THE CARE AND HANDLING OF MILK

HAROLD E. ROSS

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PREFACE

Milk and dairy products are among our most important foods. For children it is the most important of all foods. Our greater knowledge of milk, its merits as a food, its production, and its distribution, together with the growing population in the larger towns and cities all combine to make the whole subject of market milk one of our great national problems. The increased use of milk means that new problems will constantly arise in the production and handling of market milk and it is only by constant study that these problems can be met and solved.

This book is intended as a text for dairy students and as a guide for all who are interested in the care and handling of milk, and in its use as a food. In preparing this book references have been made to the latest investigations along the several lines discussed, and in each case credit has been given to the writers and investigators quoted.

The author wishes to acknowledge the helpful suggestions of his colleagues in the Department of Dairy Industry at Cornell University and also the courtesies shown by D. H. Burrell & Co., the General American Car Co., and the Chestnut Farms Dairy for cuts and drawings. In each case credit for the use of this material has been given.

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H. E. ROSS.

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THE CARE AND HANDLING OF MILK

Chapter I

SIZE AND IMPORTANCE OF THE DAIRY INDUSTRY

Milk and dairy products have been used as human food for centuries. To-day more of each of these products is consumed per capita than ever before in the history of the world. There are several reasons why this is the case and these reasons may be stated as follows:

1. Milk and dairy products are from all standpoints among our best foods. This point is fully discussed in Chapter VII on the Food Value of Milk.

2. Milk is ready for consumption without cooking or any other preparation.

3. Milk is the one food which is most nearly complete, and for which as yet there has been found no substitute.

4. The general consuming public is being educated in regard to the value of milk as a food. Consumers are purchasing more of milk and using it in place of other foods, as, for instance, in place of meat.

5. Through sanitary systems of production and handling, milk is more wholesome than formerly. This means that people have more confidence in it and use more of it.

6. Systems of transportation are being constantly improved, making it possible to get milk to market in better condition and to haul it over longer distances. Two good examples of such transportation are the automobile truck and the glass-lined tank car.

7. New ways are constantly being found to use milk as a human food and this greatly increases the consumption of milk.

8. A large variety of food products, which have excellent food value, can be manufactured from milk. Many of these products differ widely from one another in texture and flavor, and this means that dairy products may be used for a long time without the consumer becoming tired of them.

9. Some of the by-products of milk have uses in industries other than as a food. A good example of this is casein products, whose uses are steadily extending.

Authorities differ as to the exact amount of dairy products used in the average American family. The consensus of opinion is that about one-fifth of the money expended for food is used in purchasing dairy products. While this may seem like a large proportion, all dieticians are agreed that both from a dietetic and economic standpoint more dairy products should be used.

In table number 1 is given the total dairy cattle and the pounds of milk produced in the United States for the years 1917 to 1923 inclusive.[1]

Table 1.—Number of Dairy Cows and Their Production (1917-1923).

	1917	1918	1919	1920
Total dairy cattle.....	22,894,000	23,310,000	23,455,000	23,722,000
Total pounds milk produced	84,612,000,000	87,906,000,000	90,058,000,000	89 657,000,000

	1921	1922	1923
Total dairy cattle.....	23,594,000	24,028,000	25,752,000
Total pounds milk produced	98,862,000,000	102,562,000,000	109,736,062,000

From this table it may be seen that over a period of seven years, there has been a gradual increase in both the number of cattle and the amount of milk produced.

Table 2, the figures for which were taken from the 1923 Year Book, shows the value of milk and dairy products in the United States for a period of five years beginning with 1919.

[1] The figures for these tables were taken from statistics published by the U. S. Dept. of Agriculture. Most of them were obtained from a Hand Book of Dairy Statistics, by T. R. Pirtle, and from some advance statistics furnished by Mr. Pirtle; also from the Year Book 1923.

Table 2.—Value in Dollars of Milk and Dairy Products, in the United States from 1919 to 1923.

Product	1919	1920	1921	1922	1923
Milk sold	1,041,236,000	1,033,008,000	836,868,000	721,677,000	910,723,000
Milk consumed on farms	817,938,000	878,062,000	730,564,000	635,573,000	784,836,000
Total whole milk	1,859,174,000	1,911,070,000	1,567,432,000	1,357,250,000	1,695,559,000
Butter made	344,877,000	366,174,000	241,560,000	220,187,000	246,318,000
Cheese made	2,376,000	2,334,000	1,639,000	1,175,000	1,183,000
Cream sold	109,359,000	116,588,000	80,579,000	70,275,000	97,721,000
Butter fat sold	398,003,000	404,384,000	364,180,000	344,285,000	379,200,000
Buttermilk	13,402,000	11,754,000	4,644,000	4,292,000	6,273,000
Whey	231,000	196,000	77,000	61,000	86,000
Skimmilk from butter, butter fat and cream sold	233,012,000	205,480,000	91,700,000	92,931,000	139,537,000
Total value of products	$1,101,260,000	1,106,910,000	784,379,000	733,205,000	870,318,000
Grand total whole milk and products	$2,960,434,000	3,017,980,000	2,351,809,000	2,090,455,000	2,565,877,000

It will be noted that dairy products reached their maximum value in 1920. The value of dairy products in the United States for the year 1923 was over two and one-half billion dollars and this figure is probably a conservative one, as ice cream is not mentioned, although the value of the cream which went into the product was taken into account.

There were produced in the year 1922 in the United States, 102,562,000,000 pounds of milk and 45.5 per cent or 46,672,600,000 pounds were consumed as fluid milk or as cream. This is a large amount, yet the per capita consumption is, as previously stated, very small, and far below what it should be. This is borne out by the figures in the following table number 3.

Table 3.—Daily Per Capita Consumption of Milk in the United States for Different Years.

Year	1917	1920	1921	1922	1923
Daily per capita consumption (pints)	.92	.94	1.07	1.09	1.16

The encouraging feature about this table is the fact that while the per capita consumption is small, it is steadily increasing, although at a slow rate.

In table number 4 is shown the annual per capita consumption of butter and cheese in the United States.

Table 4.—Butter and Cheese Consumed in United States.

	Year					
Kind of Product	1909	1919	1920	1921	1922	1923
Butter (lbs.)	17.5	14.8	14.7	16.1	16.5	17.0
Cheese (lbs.)	...	4.2 *	3.5	3.5	3.7	3.9

* Includes cottage cheese.

We do not consume as much butter or cheese per capita as some foreign countries (see Chapter VII). In Canada, for example, about 27 pounds of butter and in Switzerland about 20 pounds of cheese is consumed per person. While our consumption of butter is fairly large, our cheese consumption is pitifully low when its high food value is considered.

The next table gives the number of pounds of milk produced in the United States in the years 1919-1923 inclusive, together with the uses made of this milk, expressed in terms of percentage.

Table 5.—Total Milk Production in the United States.

Year	Total Pounds Milk Produced	Per Cent Used as Fluid Milk	Per Cent Used in Manufacturing	Per Cent Fed to Calves	Per Cent Waste, Loss and Unspecified
1919.....	90,057,500,000	42.882	50.359	3.886	2.873
1920.....	89,657,300,000	43.600	48.685	4.688	3.027
1921.....	98,862,300,000	45.660	47.030	4.310	3.000
1922.....	102,562,200,000	45.507	47.267	4.226	3.000
1923.....	109,736,062,000	45.965	47.232	3.803	3.000

One thing about this table deserving particular notice is the uniform balance from year to year between the different uses made of the milk. Another noticeable feature is the small percentage of loss. When one stops to consider the large amount of handling to which fluid milk is subjected, and the various forms of edible products made from milk, approximately 3 per cent loss is remarkably low.

Reasons have been given as to the desirability of having more dairy products used in the diet. There are three factors which will hasten this. The first one is in educating the consuming public about the high food value of milk and dairy products, and the economy involved in their use, neither of which is much realized by the average consumer. The second factor is cleanliness and purity of dairy products. The consuming public will not use a food product unless it has every confidence in its wholesomeness. The third essential factor is standardization of dairy products. No matter how wholesome and palatable a product may be, if it is different from what the consumers have been accustomed, they will not use it.

Chapter II

SOME CHEMICAL AND PHYSICAL PROPERTIES OF WHOLE MILK

Milk is the fluid secreted by mammals for the nourishment of their young. In the case of wild animals, the period of lactation is usually short, being just long enough to allow the young to attain sufficient size so as to subsist on other food. In the dairy cow, the function of milk production has been so stimulated by methods of breeding and feeding that the lactation period usually lasts ten months of the year and in many cases where the animal is a high producer, the lactation period may last a whole year or longer.

Milk contains many different ingredients, some of which are in suspension and some in solution. There are, however, six constituents which comprise the general composition of milk. They are as follows, as shown in Table 6:

	Per Cent		Per Cent
Water	87.0	Casein	2.6
Fat	4.0	Albumin	0.7
Sugar	5.0	Ash	0.7

This is a fair representation of the composition of average normal milk but the composition varies because of a great many different conditions. There are in addition to the substances mentioned many other constituents, which, although not present in large percentage amounts, yet have an important effect on the action of milk under varying conditions. Among these constituents may be mentioned, carbon dioxide, oxygen, enzymes, leucocytes and fibrin.

The following table by S. M. Babcock gives a clear and concise idea of the composition of milk. In studying this table it will be noted that some of the constituents are present in small amounts. It must not be inferred, however, that for this reason they are unimportant; indeed, from a food standpoint they are of very great importance.

Table 7.—Composition of Cow's Milk (after Babcock).

Milk = 100.0	Butter fat = 3.6	Olein		Glycerides of insoluble and nonvolatile acids	3.3	Fat	3.6	Total solids 12.7
		Palmitin						
		Stearin						
		Myristin						
		Butin (trace)						
		Butyrin		Glycerides of soluble and volatile acids	0.3			
		Caproin						
		Caprylin (trace)						
		Caprinin (trace)			3.6			
	Milk serum 96.4	Casein	3.00	Containing nitrogen	3.8	Solids not fat	9.1	
		Albumin	0.60					
		Lactoglobulin, Galactin, Fibrin (trace)	0.20					
			3.80					
		Milk sugar			4.5			
		Citric acid			0.1			
		Potassium oxide	0.175	Ash	0.7			
		Sodium oxide	0.070					
		Calcium oxide	0.140					
		Magnesium oxide	0.017					
		Iron oxide	0.001					
		Sulphur trioxide	0.027					
		Phosphoric pentoxide	0.170					
		Chlorine	0.100					
			0.7		9.1		12.7	
		Water						87.3
	100.0							100.0

Milk is variable in composition and table number 8 gives an idea of the range of variation:

Table 8.—Maximum and Minimum Variation in Cow's Milk.

	Maximum Variation	Minimum Variation
Water	90.52	80.50
Fat	8.20	1.69
Casein	4.20	1.82
Albumin	1.35	.25
Sugar	6.10	2.51
Ash	1.20	.38

The above variations cover quite a wide range but some of the above constituents have a wider range than is indicated in this table. The maximum fat of 8.20 per cent given is from an analysis made by the author. The sample was apparently normal and the animal from which the sample was drawn was under official test.

The different constituents of milk are separated into various groups and these groups are given special names. The fat, sugar, casein, albumin and ash make up the total solids of milk. The sugar, casein, albumin and ash make up the solids not fat; while milk from which the fat has been removed is called skimmilk or milk serum.

The milk which is secreted just before or just after the birth of the calf is of a different character and composition than normal milk. This milk is called colostrum and it is as variable in composition as is normal milk.

The following table taken from different analyses gives some idea of the variation of the different constituents:

Table 9.—Showing Variation in Composition of Colostrum Milk.

	Sample No. 1	Sample No. 2
Water	70.42	76.25
Fat	1.42	6.32
Sugar	1.50	2.50
Proteids	24.35	14.52
Ash	1.09	1.09

The length of time which the colostrum stage exists varies with different animals. This milk is thought to be very valuable for the young animal and is said to be stimulating to the digestive tract.

The entire proteid content of colostrum is high and this is especially true of the albumin, which is present in such large quanti-

ties that the colostrum will thicken on boiling. Boiling is sometimes used as a rough test to determine whether or not milk has passed the colostrum stage.

The fat globules in colostrum are usually much larger than those of normal milk, and they rapidly approach their normal size as the colostrum stage disappears.

In nearly all countries the cow is used as the chief milk producing animal. She has been bred and selected for so many years for this purpose, that the quality and quantity of her milk makes her by far the most economical source of the milk supply. In some countries, however, the milk of other animals is used, among which may be mentioned the goat, reindeer, sheep, mare and ass.

The following table [2] gives the percentage composition of milk given by different animals. This table is interesting both from the scientific standpoint, and also from the standpoint of the food value of milk. The latter point will be fully discussed in another chapter.

Table 10.—Showing Average Composition of Milk Given by Different Animals and Also the Composition of Human Milk.

Kind of Milk	Water	Total Solids	Protein			Fat	Carbohydrates (milk sugar)	Mineral Matter
			Casein	Albumin	Total			
	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
Woman	87.58	12.6	0.80	1.21	2.01	3.74	6.37	0.30
Cow	87.27	12.8	2.88	.51	3.39	3.68	4.94	.72
Goat	86.88	13.1	2.87	.89	3.76	4.07	4.64	.85
Sheep	83.57	16.4	4.17	.98	5.15	6.18	4.73	.96
Buffalo (Indian)	82.16	...	4.26	.46	...	7.51	4.77	.84
Zebu	86.13	...	...	...	3.03	4.80	5.34	.70
Camel	87.13	...	3.49	.38	...	2.87	5.39	.74
Llama	86.55	...	3.00	.90	...	3.15	5.60	.80
Reindeer	67.20	...	8.38	1.51	...	17.09	2.82	1.49
Mare	90.58	9.9	1.30	.75	...	1.14	5.87	.36
Ass	90.12	10.4	.79	1.06	1.85	1.37	6.19	.47

There are quite a number of different factors that affect the composition of milk. Some of these exert a very great influence on the variation of the different constituents of milk, while other factors exert only a slight influence, which are, however, none the less definite. It will be noticed that much of the discussion of the variation of the composition of milk is based on a variation of the milk

[2] Milner, R. D., The use of milk as a food, U. S. Dept. of Agriculture Farmers' Bull. No. 363.

fat. This is because fat is one of the most important constituents of milk. Furthermore, the solids not fat of milk increase as the fat increases, although after a certain point is reached they do not increase in the same proportion.

It should, perhaps, be pointed out that securing data in regard to factors affecting the composition of milk is not as easy as it might at first seem to be the case. There are so many factors influencing the composition of milk that it is difficult to eliminate other factors than the one being studied. The following discussion will take up some of the factors influencing the composition of milk.

1. Influence of breed.—It is well known that certain breeds give milk which normally contains a high percentage of fat while the milk from other breeds normally contains a low percentage of fat. In some cases those breeds which give milk of a low percentage of fat give a large quantity of milk and so the total amount of fat given by them during a lactation period is large.

The following table by Eckles and Shaw [3] as reported by American Experiment Stations shows the average percentage of fat in milk from different breeds of dairy cattle.

Table 11.—Showing the Average Percentage of Fat in Milk from Different Breeds of Cattle.

Breed	Average Percentage of Fat
Jersey	5.14
Guernsey	4.98
Ayrshire	3.85
Holstein	3.45
Shorthorn	3.63

The same authors found that a breed also exerts an influence on other milk constituents, although the percentage of these constituents was not affected as much as is the fat.

There is a distinct variation in percentage of casein due to breed as shown in the following table in which the results are expressed in terms of the ratio of fat to casein.

Table 12 indicates that the breeds having the widest ratio between the fat and casein are those giving the highest percentage of

[3] Eckles, C. H., and Shaw, R. H., The Influence of Breed and Individuality on the Composition and Properties of Milk, U. S. Dept. of Agr. Bull. No. 150.

Table 12.—Showing the Ratio of Fat to Casein in Milk from Different Breeds of Cattle.

Breed	Ratio of Fat to Casein
Jersey	1.69: 1
Ayrshire	1.36: 1
Shorthorn	1.36: 1
Holstein	1.31: 1

fat in the milk and this fact is also substantiated by the work of Hart.[4]

Breed does not seem to exercise any influence on the percentage composition of the ash of milk. It also has little effect upon the amount of milk sugar. Shaw and Eckles found a slightly lower percentage of sugar in the milk from Holsteins than in the milk from the other breeds of cattle examined.

2. **Individual animals of the same breed.**—It has been known for a long time that the individual animal exerts a great influence on the variation in the composition of milk. This is especially true in regard to the fat. Eckles and Shaw found that in the case of seven cows under investigation, only 56 per cent of the samples came within 0.5 per cent of the average. They found so great a variation that they concluded that a sample taken from a single milking is of little use in determining the value of a cow as a fat producer.

The same authors found that there was small variation in the percentage of protein, and that the variation of sugar was considerably greater than the variation of protein.

3. **Morning and evening milk.**—There is slight variation in the fat content of morning and evening milk, most investigators agreeing that the morning's milk has a slightly higher fat content than the evening milk. In studying this question it is important to take into account the periods between milkings as the milk drawn after the shorter period between milkings usually has a higher percentage of fat than the milk drawn after the longer period between milkings. Eckles and Shaw found, however, that there was a constant variation in the composition of the fat in evening and morning milk, the most noticeable being an increase in the volatile acids in the morning's

[4] Hart, E. B., Variations in the amount of casein in cows' milk, Journal of American Chemical Society, Vol. 30.

Table 13.—Showing Average Composition of Milk of Different Breeds for Four-Week Periods.

Breed	Constituents of Milk	First Four-Week Period	Second Four-Week Period	Third Four-Week Period	Fourth Four-Week Period	Fifth Four-Week Period	Sixth Four-Week Period	Seventh Four-Week Period	Eighth Four-Week Period	Ninth Four-Week Period	Tenth Four-Week Period	Eleventh Four-Week Period	Twelfth Four-Week Period	Thirteenth Four-Week Period	Fourteenth Four-Week Period
Jersey	Fat	5.20	4.91	5.02	4.79	4.88	4.98	4.93	4.83	4.84	4.88	5.23	5.68	5.48	6.47
	Albumin	.313	.408	.306	.319	.313	.306	.319	.338	.338	.370	.332	.334	...	...
	Casein	2.74	2.36	2.87	2.81	3.00	3.00	3.00	3.00	3.06	3.13	3.25	3.45	...	...
	Sugar	4.92	4.87	4.91	4.96	5.00	4.90	4.70	5.00	4.62	4.79	4.96	5.16	4.46	5.22
	Total solids	14.13	13.59	13.93	13.80	13.60	14.07	14.02	14.06	13.92	14.43	14.79	15.58	16.10	17.16
Holstein	Fat	3.14	2.87	2.78	3.11	3.11	2.98	3.03	3.09	3.05	3.31	3.39	3.70	4.48	3.68
	Albumin	.287	.198	.211	.198	.204	.230	.255	.255	.217	.274	.345	.262	.198	...
	Casein	2.42	2.11	2.04	2.17	2.23	2.30	2.30	2.36	2.42	2.74	2.25	3.32	3.51	...
	Sugar	4.39	4.49	4.48	4.42	4.70	4.59	4.70	4.32	4.54	4.56	4.81	4.59	4.60	4.81
	Total solids	11.31	10.64	10.84	11.10	11.27	11.15	11.31	11.40	11.51	12.20	12.83	13.01	13.28	13.42
Ayrshire	Fat	3.94	3.68	3.60	3.59	3.70	3.52	3.63	3.74	3.71	4.05	4.92	3.96	4.18	...
	Albumin	.262	.204	.223	.211	.236	.242	.230	.179	.160	.217	...	...	...	...
	Casein	2.93	2.55	2.55	2.62	2.62	2.62	2.62	2.74	3.13	3.25	...	...	...	...
	Sugar	5.16	4.77	5.13	5.02	4.87	4.26	5.10	5.11	4.99	4.64	4.89	5.04	5.13	...
	Total solids	13.14	12.39	12.36	12.23	12.38	12.11	12.01	12.40	12.53	12.82	13.55	13.04	13.27	...
Shorthorn	Fat	4.08	3.88	3.71	3.54	3.56	3.58	3.69	3.73	4.19	4.19	4.11	...	...	...
	Albumin	.338	.325	.262	.281	.287	.255	.274	.281	.357	.338	.383	...	...	...
	Casein	2.81	2.62	2.49	2.55	2.68	2.81	2.87	2.93	3.06	3.19	3.25	...	...	...
	Sugar	5.13	5.20	5.31	4.95	4.67	5.07	5.11	4.01	4.45	4.23	4.36	...	...	...
	Total solids	13.43	12.91	12.62	12.37	12.59	12.56	12.92	12.84	13.07	13.09	13.02	...	...	...

milk. There was not, however, much variation in the other milk constituents.

4. The stage of lactation period exerts a big influence on the composition of milk.—As already stated the colostrum milk is high in ash and protein, especially albumin. These decline as the milk approaches its normal composition.

The influence of the stage of lactation period on the composition of milk was studied by Eckles and Shaw [5] and is shown in Tables 13 and 14. The data in these tables were compiled from U. S. Department bulletin 155 by the two investigators and the figures given are for fourteen four-week periods.

Table 14.—Showing Grand Total Average Composition of Milk of Different Breeds for Four-Week Periods.

Grand Total Average for Jerseys, Holsteins, Ayrshires and Shorthorns	First Four-Week Period	Second Four-Week Period	Third Four-Week Period	Fourth Four-Week Period	Fifth Four-Week Period	Sixth Four-Week Period	Seventh Four-Week Period
Fat	4.00	3.85	3.79	3.77	3.82	3.79	3.83
Albumin	.300	.287	.255	.255	.262	.268	.274
Casein	2.68	2.36	2.49	2.49	2.62	2.68	2.68
Sugar	4.87	4.84	4.94	4.82	4.80	4.75	4.88
Total solids	12.74	12.26	12.29	12.24	12.35	12.50	12.61

Grand Total Average for Jerseys, Holsteins, Ayrshires and Shorthorns	Eighth Four-Week Period	Ninth Four-Week Period	Tenth Four-Week Period	Eleventh Four-Week Period	Twelfth Four-Week Period	Thirteenth Four-Week Period	Fourteenth Four-Week Period
Fat	3.85	3.97	4.11	4.22	4.54	4.66	5.08
Albumin	.268	.281	.306	.332	.357	.29	.287
Casein	2.74	2.87	3.06	3.19	3.38	3.64	3.70
Sugar	4.83	4.62	4.55	4.74	4.91	4.50	5.01
Total solids	12.70	12.78	13.16	13.46	14.04	14.23	15.29

A study of the tables shows that the fat is slightly higher during the first four-week period, after which there is a slight decrease in percentage of fat. From this point there is not much change in the percentage composition until near the end of the lactation period, at which time the fat increases quite rapidly until the end of the lactation period.

The casein increases very materially from the beginning of the

[5] Eckles, C. H., and Shaw, R. W., The Influence of the Stage of Lactation on the Composition and Properties of Milk, U. S. Dept. of Agr. Bull. No. 155.

lactation period to the close. This is shown in table 13 by comparing the casein content of the milk from the four breeds of cattle studied; this fact is also borne out in table 14 by comparing the grand total average percentage of casein in the milk of all the four breeds studied.

It should be pointed out that the percentage of albumin given in tables 13 and 14 is only a little more than half the average percentage composition of normal milk which is about 0.7 per cent. This is because only that part of the albumin was considered which could be precipitated by heat and removed by filtering.

There is very little change in the percentage composition of sugar during the lactation period. In some cases it increases slightly and in some cases decreases slightly toward the close of the lactation period. The total solids of milk increase very materially toward the close of the lactation period, although this increase is sometimes not very marked until the normal volume of milk given shows a decided decrease. This is shown clearly in table 13, in which the Shorthorn breed gave milk of less solid content during the eleventh four-week period than during the two previous four-week periods. This increase in solid content is to be expected. The fat and casein together make up an average of about 50 per cent of the total solids of milk and the fat, casein and sugar make up approximately 88 to 90 per cent. Since the fat and casein increase with the stage of the lactation period and the sugar remains quite constant it is only to be expected that the total solids of milk would increase with the stage of the lactation period.

5. Stage of milking.—The first milk drawn from the udder of the cow is very low in fat content, sometimes testing below 1 per cent. That which is drawn after the first few streams have been removed is very close to the average percentage of fat content of the entire milking, while the strippings are very rich in fat, often containing more than 8 per cent.

The other constituents of milk are very little affected by the stage of the milking period except as they may be slightly affected by the variation in fat content. The following tables taken from the work of Eckles and Shaw [6] give the percentage composition of fore milk

[6] Eckles, C. H., and Shaw, R. H., Variations in composition and properties of milk from the individual cow, U. S. Dept. of Agr. Bull. No. 157.

and strippings, and also of milk serum. The latter table proves that the solids not fat are only slightly affected in composition by the stage of the milking period.

Table 15.—Showing the Percentage Composition of Fore Milk and Strippings.

	Total Protein	Sugar	Fat	Ash	Total Solids
Fore milk	3.58%	5.30%	1.87%	0.75%	10.67%
Strippings	3.38%	5.33%	6.28%	0.70%	14.86%

Table 16.—Showing the Percentage Composition of Milk Serum from Fore Milk and Strippings.

	Total Protein	Sugar	Ash
First milk	3.65%	5.40%	0.77%
Strippings	3.60%	5.68%	0.75%

The reason generally given for the increase in fat in strippings is that the larger fat globules become entangled in the small milk ducts of the udder, and become loosened as the last few streams are drawn. Eckles and Shaw point out that their work supports this theory, because the greater the amount of milk produced the greater was the increase of fat as the process of milking neared completion. Still further proof of their theory is given in the fact that the fat globules in the strippings are usually twice and sometimes nearly three times the size of those found in the fore milk.

6. Age of cow.—The influence of the age of the cow upon milk composition has been studied largely from the standpoint of fat production. Wing and Anderson [7] studied this question for a number of years with a herd of about 20 cows, and the following table, taken from Bulletin 169, Cornell University Experiment Station, summarizes fairly well the results of the work obtained on this question.

In studying the figures in Table 17, it will be noticed that the older cows gave more milk and more fat than the cows at four years of age. The animals 8 and 9 years of age did not give as much milk and fat as those 7 years old, but whether this decline in production would have continued after the eighth and ninth years cannot be told. There was a slight increase in percentage of fat in the milk from the cows 8 and 9 years old over that given by the younger

[7] Wing, H. H., and Anderson, Leroy, Studies in Milk Secretion, Cornell University Bulletin No. 169.

Table 17.—Production and Percentage of Fat in Herd Milk Composed of Cows of Different Ages.

Age of Cow	No. of Cows	Pounds of Milk	Pounds of Fat	Average Per Cent Fat
2 year olds	25	5844.99	215.85	3.71
3 year olds	25	6133.69	227.76	3.71
4 year olds	18	7238.83	266.33	3.68
Full aged cows	29	8346.66	302.52	3.62
5 year olds	12	7893.08	283.96	3.60
6 year olds	8	8430.22	294.15	3.49
7 year olds	5	9143.95	336.29	3.68
8 and 9 year olds	4	8543.63	332.75	3.89
Average	97	6925.97	255.85	3.67

animals, but the difference in percentages of fat given by the herds of different ages is not variable enough to have any significance.

In the investigation already referred to, there were three cows which were included in the experiment until 8 years of age. Table 18 gives a comparison of the average pounds of milk, average pounds of fat and the average percentage of fat in the milk given by these cows at the respective ages of 4 and 8 years.

Table 17 shows that in the case of the herd studied there was an increase both in the number of pounds of milk and pounds of fat up to the time the cows were 8 years of age. The percentage of fat also remained practically the same.

Table 18.—Average Pounds Milk, Average Pounds Fat, and Average Percentage of Fat in the Milk in a Group of Three Cows at 4 and 8 Years.

No. of Cows	Average Pounds Milk at		Average Pounds Fat at		Average Per Cent Fat at	
	4 Years	8 Years	4 Years	8 Years	4 Years	8 Years
3	7310.41	9488	285.84	343.94	3.91	3.62

In Table 18 the figures show that for the group of three cows more milk and more fat were given at 8 years of age than at 4 years of age. The percentage of fat in the milk was less in the aged group, although this decline in percentage of fat is easily within the limits of a normal herd variation.

Eckles and Palmer [8] studied the effect of age on composition of milk from three different breeds. They found there was a tendency for some breeds to give the richest milk during the first lactation

[8] Eckles, C. H., and Palmer, L. S., Influence of age of cow on milk and milk fat, Journal of Agricultural Research, Vol. XI, No. 12.

period, and others to reach a maximum fat production later in life. They also found that there was a gradual decline in percentage of fat as the cow advanced in years and while this decline was not great it was none the less definite. Eckles and Palmer failed to find any change in composition of milk fat due to age. The fat from four cows, 19 years old, was examined and made into butter and the butter was judged to be normal in every way. This result was contrary to the statement of some foreign investigators that butter made from milk of old cows is abnormal.

Hills [9] found that advanced age tended to lower slightly the solid content of milk. Table 19 taken from the 19th annual report of the Vermont Experiment Station, summarizes quite clearly the results of Hill's work.

Table 19.—Effect of Age of Cow on the Composition of Milk.

	2ND YEAR	3RD TO 4TH YEAR	5TH TO 8TH YEAR	9TH TO 11TH YEAR
Total solids	14.98	14.87	14.68	14.63
Fat	5.43	5.34	5.30	5.27
Solids not fat.....	9.55	9.54	9.39	9.34

7. Health of the animal.—The health of the animal may affect the composition of milk but no prediction can be made as to whether the constituents will increase or decrease. So far as the fat is concerned its percentage is quite liable to increase, because it usually happens that the quantity of milk materially decreases when the animal is taken sick. Excitement or abnormal conditions of any kind may produce changes in the composition of milk given by an animal.

8. Effect of feed.—A great deal of work has been done on the effect of feed on the composition of milk and most of the observations have been on the influence of feed on the fat content. In some instances the rations given have undoubtedly produced abnormal changes in the animal and it is difficult to determine whether the results obtained were due to the ration or to the abnormal changes produced in the animal. A review of the experimental work done along this line indicates that underfeeding, or feeding rations deficient in one or more of the digestible nutrients produces more

[9] Hills, J. L., The effect of age on the yield and quality of milk, 19th report, Vermont Agricultural Experiment Station, 1905-1906.

changes in the composition of milk than does the addition of different materials to a liberal ration.

Van Slyke [10] found that the milk from cows fed on pasture during a drought contained a higher percentage of fat than at other times and that there was also at this time a decrease in the percentage of casein. The proportion of casein to fat likewise decreases. Table 20, the figures of which were taken from bulletin 105 of the Geneva Experiment Station, shows the effect of drought on the composition of milk. It will be noted in this table that during the months of June and July there was an actual increase in fat and a decrease in casein, and that while in August the casein increased slightly over the previous month, yet the proportion of casein to fat was diminished.

Table 20.—The Effect of Drought on the Composition of Milk.

Month	Lbs. Fat in 100 Lbs. Milk	Lbs. Casein in 100 Lbs. Milk	Lbs. Casein for 1 Lb. Fat in Milk
May	3.58	2.40	0.67
June	3.59	2.33	0.65
July	3.71	2.20	0.59
August	4.04	2.26	0.56
September	3.97	2.47	0.62
October	4.20	2.69	0.64

It should be further noted that during September and October the normal relation between casein and fat was gradually restored. Van Slyke advises that some succulent feed be fed during the months of drought to prevent the decrease in the proportion of casein to fat.

Eckles and Palmer [11] found that giving a milch cow less feed than was required for bodily maintenance and milk production, or in other words, underfeeding the cow, changed the composition of the milk and this was especially noticeable in an increase in butter fat. Changes were produced in some of the other milk constituents but these changes were not uniform. In no case was the percentage of milk sugar affected.

[10] Van Slyke, L. L., Effect of Drouth Upon Milk Production, Bull. 105, New series, N. Y. State Exp. Station, Geneva, N. Y.

[11] Eckles, C. H., and Palmer, L. S., Influence of plane of nutrition of the cow upon the composition and properties of butter fat. Influence of underfeeding, Bull. 25, Mo. Agr. Exp. Station.

The same authors [12] also found that giving a milch cow more feed than was required for bodily maintenance and milk production or, in other words, overfeeding the cow, did not affect the composition of the milk. This was true when the animal was receiving a normal ration. If the cow had been underfed, and the composition of the milk thereby affected, overfeeding brought the composition of the milk back to normal again.

In an experiment conducted over a period of two years, Wing and Foord [13] were able by liberal feeding to increase the fat content of the milk of a herd one fourth of one per cent. This herd had been previously underfed. It is very possible that in view of the facts obtained by Eckles and Palmer, that feeding the liberal ration merely brought the herd up to the normal fat production.

Wing [14] attempted to increase the percentage of fat in milk by adding tallow to the regular ration. Although as high as two pounds of tallow per day were fed to each cow, no increase in percentage of fat was obtained.

It is the general concensus of opinion of investigators that if a milch cow is receiving a sufficient balanced ration, feed has practically no influence on the composition of milk.

9. Percentage of fat in milk from different quarters of the udder.—The percentage composition of milk from different quarters of the udder has been studied only from the standpoint of its fat content. Beach and Clark [15] found a variation in the percentage of fat from different quarters of the udder of individual cows. They found, however, that in one trial from a herd of 15 cows there was very little variation in the average percentage of fat from different quarters of the udder.

Fitch and Copeland [16] found that in certain individuals there was a marked difference in the percentage of fat from different quarters of the udder. They also found that those quarters giving the least milk gave the highest percentage of fat.

[12] Eckles, C. H., and Palmer, L. S., Influence of the plane of nutrition of the cow upon the composition and properties of milk and butter fat. Influence of overfeeding, Bull. 24, Mo. Agri. Exp. Sta.

[13] Wing, Henry H., and Foord, James A., An attempt to increase the fat in milk, Bull. 222, Cornell University.

[14] Wing, Henry H., Feeding fat to cows, Bull. 92, Cornell University.

[15] Beach, C. L., and Clark, A. B., Yield of front and rear udder of the cow, Storrs Report 1904.

[16] Fitch, J. B., and Copeland, Lynn, Journal of Dairy Science, Vol. 7, No. 2, pg. 169.

The investigators worked with five cows and examined the night and morning milk on two successive days. The experiment was repeated after an interval of two weeks, thus making eight samples obtained from each quarter of the udder from each cow. In Table 21 is given the average percentage of fat obtained from each quarter of the udder. The figures represent the average of the four samples taken at each trial. The grand total average percentage is the average of all the samples, 40 in all, taken from each quarter of the udder of the five different cows.

Table 21.—Average Percentage of Fat in Milk from Different Quarters of the Udder.

Number of Cow	Number of Trial	Average Per Cent of Fat in Milk			
		Fore Udder		Rear Udder	
		Right	Left	Right	Left
I	1	4.14	4.40	4.825	4.30
	2	4.40	4.80	4.90	4.475
II	1	3.075	3.512	3.21	3.10
	2	3.425	3.675	3.60	3.60
III	1	5.11	5.775	5.41	5.25
	2	5.35	5.675	6.10	5.45
IV	1	6.00	6.45	5.675	5.725
	2	6.175	6.275	6.450	6.075
V	1	4.475	5.50	5.31	5.075
	2	4.525	5.950	5.675	5.35
Grand total average percentage		4.6675	5.17	5.1115	4.840

Chapter III

SOME CHEMICAL AND PHYSICAL PROPERTIES OF THE CONSTITUENTS OF MILK

Water.—The water in milk is about 87 per cent of the total weight of the milk, and it is chemically no different from water found elsewhere. It serves a useful purpose, however, as it may be regarded as a carrier for the solid contents of milk, some of which are dissolved in the water and some of which are in very fine suspension.

Fat.—Milk fat, often referred to as butter fat, is present in milk in the form of an emulsion and forms approximately 26 per cent to 33 per cent of the total solids of milk. The fat particles vary in size from about .00395 mm. to .0025 mm. The chief factors affecting the size of fat globules are the breed and the period of lactation. The breeds of animals giving high percentage of fat have much larger fat globules than those giving low percentages of fat. Woll [17] gives these a relative size of 290:177 respectively. The fat globules are larger during the early stages of the lactation period and gradually diminish in size as the period of lactation advances. The number, as might be expected, increases as the period of lactation advances and the globules become smaller. Woll gives the relative number at the beginning and close of the lactation period as 138:367 respectively, and the relative size at the beginning and close of the lactation period as 348:149 respectively.

Plate 1 taken from B. A. I. Bulletin 156, by Eckles and Shaw, shows graphically the relative size of fat globules from the milk of different breeds of cows.

The fat globules will rise to the surface of the milk if the milk is left standing for any length of time and in a glass container such as a milk bottle this line of demarcation can usually be readily distinguished, and is known as the cream line. However, the fact that

[17] Woll, F. W., Wisconsin Report for 1894.

milk does not have a long cream line is not proof positive that the milk is low in fat content. All of the reasons why milk rich in fat will not show a cream line are not known, but probably one of the factors exerting the greatest influence is the size of the fat globules; the larger the fat globules, the easier and more complete the separation of fat. It has been the opinion of some investigators that the fat globule is surrounded by a membrane, but this opinion is not supported by more recent experimental work. It is thought that the fat globule retains its circular shape because of the surface tension of the fat globule and also because of pressure of the milk serum on the particles of fat. In view of this fact anything which increased the viscosity of the milk serum would prevent the fat globules from rising. In any process of separation the fat globules

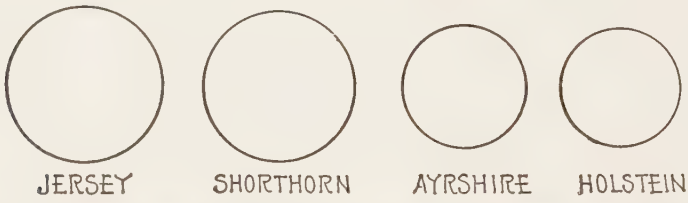

PLATE 1. Relative Size of Fat Globules from Milk of Different Breeds of Cows.

left behind are the smaller ones because a small sphere has more surface in proportion to its solid content than has a large sphere, and the viscosity of milk or pressure of milk serum would be greater on a small globule in proportion to its mass than it would on a larger globule. Milk fat is of a characteristic yellow color, but the intensity of the color depends on the food eaten by the animal producing it. In summer when the cow is eating pasture the fat becomes a deep yellow, while during the winter months when pasture is not available and the animal is fed cured fodder, the fat becomes a pale yellow.

According to Palmer and Eckles [18] the color of fat is due to two pigments, carotin and Xanthophylls, which are found in green plants accompanying the chlorophyll. These pigments are not synthesized in the cow's body but are taken from the green food eaten by the animal. If an animal is producing milk fat of a pale yellow color

[18] Palmer, L. S., and Eckles, C. H., Carotin, the Principal Natural Yellow Pigment of Milk's Fat, Missouri Research Bulletin No. 10.

and these pigments are added, the fat will gradually assume a deep yellow color. On the other hand, fat having a deep yellow color will become pale if these pigments are withdrawn from the ration.

The melting point of milk fat is not constant and this variability is probably due to the fact that the composition of fat is variable. The melting point varies from approximately 30° C. to 36° C. (86° F. to 96.8° F.).

The solidifying point of milk fat is also variable and is usually given as varying from 20° C. to 27° C. (68° F. to 80.6° F.).

The specific gravity of milk fat ranges from .92 to .94 at a temperature of 15° C. (59° F.).

Milk fat is composed of ten different fats. These fats are triglycerides of the different fatty acids and milk fat may be split up into glycerine and the different fatty acids of which milk fat is composed.

Browne [19] gives the following composition of milk fat:

Table 22.—Composition of Milk Fat.

Dioxystearin	1.04	Laurin	2.73
Olein	33.95	Caprin	0.34
Stearin	1.91	Caprylin	0.53
Palmatin	40.51	Caproin	2.32
Myristin	10.44	Butyrin	6.23

This list of fats is divided into the soluble volatile and insoluble non-volatile groups. By this is meant that the acid of which the fat is composed is soluble or non-soluble and is volatile or non-volatile as the case may be. The insoluble non-volatile group of fats is by far the largest, equaling about 90 per cent of milk fat. In this group is included palmatin, olein, myristin, stearin, dioxystearin, and laurin. The remaining 10 per cent of milk fat is made up of the volatile soluble group which contains butyrin, caproin, caprin, and caprylin. There is some dispute as to the group in which laurin belongs, some placing it in one group and some in another. These fats have different characteristics and since they vary in amount at different times, they affect the character of the milk fat as a whole.

The flavor and odor of milk fat is most closely connected with the volatile-soluble group of fats and this is especially true of butyrin, which easily oxidizes into butyric acid and glycerine and which

[19] Browne, C. A., Jr., The Chemistry of Butter Fat, Journal of American Chemical Society, Vol. 21.

gives to butter its strong rancid flavor. Olein has a low melting point and as this fat varies considerably in milk it has an influence on the hardness or softness of butter. In connection with milk fat should be mentioned lecithin, which is a phosphorized fat. It is a highly nitrogenous substance, soluble in ether and alcohol, and although of a complex nature it has been given the symbol $C_{14}H_{90}NPO_9$.

Supplee [20] and Cusick [21] have identified the breaking down of lecithin with the fishy flavor which sometimes develops in storage butter. When lecithin breaks down it forms a number of end products, one of which is trimethylamine. The odor and flavor of trimethylamine is like that of fish and it is this product which gives the fishy flavor to the butter. Supplee and Cusick caused the breaking down of lecithin by inoculating a sample of cream with Bacterium ichthyismucs and the fishy flavor was greatly increased in the presence of high acid.

It might well be mentioned at this point that the connection of lecithin with the fishy flavor of butter is a good example of the importance and necessity of research in connection with milk and dairy products. It is only until a comparatively recent date that lecithin had more than a passing interest. Research has now shown it to be of vital importance from a commercial standpoint.

Casein.—Casein is the principal proteid compound of milk forming approximately 20 per cent of the solid content and over 80 per cent of the proteid content of the milk. Casein exists in milk in what is called the colloidal state, which is a state of such fine suspension that it cannot be removed by any ordinary methods of filtration. When obtained in the pure state, it is a white powder without odor or taste. The structure of the casein molecule is very complex and various names for casein as it exists in milk and after it has been removed from milk by different reagents have been suggested. Van Slyke and Bosworth [22] give the following composition of casein:

[20] Supplee, G. C., The Lecithin Content of Butter and Its Possible Relationship to Fishy Flavor, Cornell University, Memoir No. 29.

[21] Cusick, J. T., Phosphorus in Butter, Cornell University, Memoir No. 30.

[22] Van Slyke, L. L., and Bosworth, Alfred W., Technical Bulletin No. 26, N. Y. State Experiment Station, Geneva, N. Y.

Table 23.—Percentage Composition of Casein.

	Per Cent		Per Cent
C	53.50	S	.72
H	7.13	P	.71
N	15.80	O	22.08

Based on the analysis of different investigators the percentage composition of casein as given in the above table would give a symbol for casein similar to the following: $C_{164}H_{263}N_{41}SPO_{51}$. Casein in milk is in combination with lime and for this reason the name calcium casein has been suggested for casein as it occurs normally in milk. Casein is precipitated from milk by the addition of dilute acids and by certain enzymes as pepsin and rennin. When milk sours naturally the lactic acid formed unites with the calcium, causing the casein to be precipitated. The preparation of pure casein is very difficult as it has a great affinity for calcium salts especially calcium phosphate and it is said to be almost impossible to produce casein without a trace of calcium phosphate. Van Slyke (*loc. cit.*) and Bosworth have perfected a chemical method for preparing casein which is practically ash free.

The action of acids on casein is a much disputed question. Van Slyke and Hart [23] working on this subject were of the opinion that casein united with acids forming casein salts of the acids—if lactic acid were used, casein lactate would be formed. Later L. L. Van Slyke and D. D. Van Slyke,[24] working on the same subject, came to the conclusion that with weak acids absorption takes place up to a certain point and after this point is reached, especially if the acid is strong, or the casein is left in contact with the acid for a long time, the casein is dissolved. This is especially true if the temperature is increased. Some later investigators are of the opinion that the findings of Van Slyke and Hart are correct—that casein does form salts of the acid with which it comes in contact.

When rennet or pepsin is added to milk the casein is precipitated but the coagulum is much different in appearance from that obtained with dilute acids. In the latter case the mass is flocculent, while in the former case the precipitate is firm and solid. The firm solid

[23] Van Slyke, L. L., and Hart, E. B., Some of the Relations of Casein and Paracasein to Bases and Acids and Their Application to Cheddar Cheese, N. Y. State Experiment Station, Geneva, N. Y., Bull. 261.

[24] Van Slyke, L. L., and Van Slyke, D. D., The Action of Dilute Acids upon Casein When no Soluble Compounds Are Formed, N. Y. State Experiment Station, Geneva, N. Y., Technical Bull. 3.

condition is favorable for cheese making and for this reason rennet and pepsin are used in making cheese. The name given to this coagulum is paracasein or calcium paracasein.

Casein is not precipitated from milk by heat at ordinary temperatures but it is said to be precipitated at approximately 140° C. (284° F.).

Albumin.—Albumin in milk is sometimes called lact albumin to distinguish it from albumin obtained from other sources, but so far as is known it does not differ chemically from albumin obtained from other sources. It comprises a little more than 5 per cent of the total solids of milk. Albumin is in solution and is not precipitated by weak acids, rennet or pepsin. It may be precipitated by certain reagents such as acid mercuric nitrate or phosphotungstic acid and a part of it is precipitated by heat at a temperature of about 75° C. (167° F.). When once precipitated by heat it will not redissolve in water, although it is soluble in alcohol. Much more of the albumin can be precipitated by heat if the whey is treated with lime water before heat is applied and this is especially true[25] with whey which has been treated with rennet.

The composition of albumin, with two exceptions, is very similar to that of casein. Albumin contains no phosphorus and its sulphur content is approximately 1.7 per cent, being about twice that of casein.

The form in which albumin is obtained depends somewhat on the conditions under which it is obtained. It is usually precipitated in a much more solid gelatinous mass than is casein.

In connection with albumin some investigators mention another protein which they call lacto globulin. It is held by other investigators that no such constituent of milk exists but that it is identical with albumin.

Fibrin.—Another protein found in milk is fibrin, which is present in small quantities in the form of minute threads and which is said to be identical with fibrin found in the blood. This substance was first noted and described by Babcock,[26] who brought forward the theory that fibrin influenced the creaming ability of milk. The

[25] Walker, C. C., and others, Cornell University Bull. No. 425.

[26] Babcock, S. M., The Constituents of Milk and Some of the Conditions Which Affect the Separation of Cream, Wisconsin Bull. No. 18.

presence of fibrin in milk was further noted by Doane,[27] while studying leucocytes in milk. Doane attached considerable importance to the amount of fibrin in milk in regard to a feverish condition of the udder. While he regarded both leucocytes and fibrin as normal constituents of milk, if there were present large numbers of leucocytes entangled in threads of fibrin, it indicated a feverish condition of the udder and the presence of pus cells.

Milk sugar.—Milk sugar, commonly called lactose, has the same chemical symbol as sucrose, $C_{12}H_{22}O_{11}$, and comprises between 38 per cent and 39 per cent of the total solids of milk. The specific gravity is slightly variable but is usually given as 1.525.

In the natural souring of milk the lactic acid bacteria break down the milk sugar to form lactic acid according to the following reaction: $C_{12}H_{22}O_{11} + H_2O = 4C_3H_6O_3$. The presence of this acid may be detected by the sense of smell when there has developed 0.2 to 0.25 per cent and from 0.25 to 0.3 per cent acid will cause the milk to taste sour. The percentage of acid required to cause milk to coagulate is not definite, coagulation sometimes occurring when there is only 0.4 per cent acid present, while again milk will not coagulate until 0.5 to 0.6 per cent acid has been developed. When 0.8 to 1 per cent of lactic acid has formed, the strong acid medium becomes unfavorable for the lactic acid bacteria and they cease to break down any more lactose until some of the acid is neutralized, when they will again become active. Not all of the milk sugar is converted over into lactic acid, since some goes to form CO_2 and water. It should be stated that fresh milk which has not been acted upon by bacteria will neutralize an alkali. This is due to acid salts in the milk and is called the *apparent acidity* of milk. The acidity due to the presence of lactic acid is called the *real acidity*. In the ordinary titration of milk there is no method of distinguishing between the two kinds of acidity. When litmus is used as an indicator, fresh milk will often give an amphoteric reaction—the reaction exhibits both acid and alkaline properties. If blue litmus is used, it will turn red and if red litmus is used, it will turn blue. This is due to the fact that litmus as an indicator does not represent the true end point in the titration of milk, and that when

[27] Doane, C. F., Leucocytes in Milk and Their Significance, Maryland Bulletin No. 102.

litmus is added to milk, a reaction takes place between the milk and the litmus. Blue litmus is more alkaline than the milk, and therefore gives up some of its basic properties to the milk, thereby turning it red. Red litmus is more acid than the milk and takes up some of the alkaline properties of milk, thereby turning blue.

Lactose is not as sweet as cane sugar and is not as soluble. At ordinary temperatures it requires about 6 parts of water to dissolve 1 part of lactose. It is dextro-rotary and will slowly reduce Fehling solution. The specific rotary power of lactose is $[A]D = 52.5$. It can be hydrolized by boiling with dilute sulphuric acid yielding glucose and galactose. The following formula represents the reaction which takes place:

$$\underset{\text{Lactose}}{C_{12}H_{22}O_{11}} + H_2O = \underset{\text{Glucose}}{C_6H_{12}O_6} + \underset{\text{Galactose}}{C_6H_{12}O_6}$$

Lactose, unlike sucrose, does not form alcohol under the action of ordinary yeasts. This is probably due to the fact that the yeasts which ferment sucrose do not produce the enzyme lactase. In order to ferment lactose the enzyme lactase is necessary. There is, however, one of the saccharomyces which will convert lactose into alcohol and this is taken advantage of in the manufacture of a sour milk drink known as Kephir. The yeast used in this case has been studied by Freudenreich and named by him Sarcomyces Kefir. Another yeast which forms small quantities of alcohol from lactose is Torula Amara. Lactose has the same food value as any sugar, it being a carbohydrate. In addition to its value as a food it is thought to be valuable in inducing the growth of desirable types of organisms (acid producing, non-putrefactive) in the intestinal tract.

Ash.—The ash of milk is that part which is left after burning, and its percentage composition varies the least of any of the other milk constituents. It is composed of mineral substances most of which are soluble and some of which are insoluble. Those which are insoluble are part of the calcium and phosphorus salts. According to some authorities, the ash does not correctly represent the mineral constituents of fresh, raw milk, because some of the salts are changed by the action of heat. Also it is quite likely that some of these salts do not exist independently in milk but are in chemical combination with some of the other milk constituents. This is es-

pecially true of the calcium salts which are thought to be in chemical combination with the casein. The lime salts are also supposed to control the action of rennet in cheese making. Soluble lime salts will hasten the action of rennet in cheese making, while insoluble lime salts will retard rennet action. It is a well-known fact that rennet acts quicker in milk if there is lactic acid present; and this rapidity of action is said to be due to the effect of the lactic acid in rendering the calcium salts more soluble.

Due to the fact that not all of the salts of milk are soluble and also because some of them are in combination with the proteid constituents of milk, it is very difficult to give the exact percentage composition of the ash of milk.

Van Slyke and Bosworth [28] give the following table as representing the composition of milk, including the milk salts.

Table 24.—Chemical Composition of Milk, Including Milk Salts.

	Per Cent
Fat	3.90
Milk sugar (lactose)	4.90
Proteins combined with calcium	3.20
Di-calcium phosphate ($CaHPO_4$)	0.175
Calcium chloride ($CaCl_2$)	0.119
Mono-magnesium phosphate ($MgH_4P_2O_8$)	0.103
Sodium citrate ($Na_3C_6H_5O_7$)	0.222
Potassium citrate ($K_3C_6H_5O_7$)	0.052
Di-potassium phosphate (K_2HPO_4)	0.230
Total solids	12.901

Table 25.—Grams per Liter and the Percentage Composition of the Ash of Milk.

	Grams in One Liter	Per Cent Found in Ash
Sodium chloride (NaCl)	0.962	10.61
Potassium chloride (KCl)	0.830	9.17
Mono-potassium phosphate (KH_2PO_4)	1.156	12.77
Di-potassium phosphate (K_2HPO_4)	0.835	9.22
Potassium citrate $K_3(C_6H_5O_7)$	0.495	5.47
Di-magnesium phosphate ($MgHPO_4$)	0.336	3.71
Magnesium citrate $Mg_3(C_6H_5O_7)_2$	0.367	4.05
Di-calcium phosphate ($CaHPO_4$)	0.671	7.41
Tri-calcium phosphate $Ca_3(PO_4)_2$	0.806	8.90
Calcium citrate $Ca_3(C_6H_5O_7)_2$	2.133	23.56
Calcium combined with casein	0.465	5.13

[28] Van Slyke, L. L., and Bosworth, A. W., Condition of Casein and Salts in Milk, N. Y. State Exp. Sta., Geneva, N. Y., Technical Bulletin 39.

In Table 25 is given, according to Soldner,[29] an analysis of the ash of a liter of milk in terms of grams. On a basis of the weights given the percentage composition of the ash alone has been computed.

PHYSICAL PROPERTIES OF MILK

Color.—The color of milk is not constant but varies from a pale white to a yellowish white. This variation in color is largely due to the variation in color and amount of fat contained in the milk. The work of Eckles and Shaw, reference to which was made in discussing the fat of milk, shows that the color of fat is due to the pigments corotin and Xanthophylls. A decrease in the yellow color of milk fat means a lighter colored milk, and vice versa an increase in the yellow color of milk fat means a yellow colored milk.

Some investigators mention a coloring matter of milk which they term lactochrome, but if this pigment does exist nothing is known of its chemical composition.

Taste.—Pure milk is almost tasteless. The only taste that can be assigned to it is mild and very faintly sweet. In this connection the term mild means lack of high flavor and the leaving of little or no taste in the mouth after the milk has been swallowed. Undoubtedly the taste which people often ascribe to milk is due to the results of bacterial action or to the absorption of foreign flavors as the senses of smell and taste are very closely connected and the fact that pure milk has little odor is synonymous with the lack of distinctive taste. Whatever taste there is in milk is much more pronounced if milk is slightly warm. Low temperatures will disguise bad flavors in milk.

Specific gravity.—The specific gravity of a substance is the weight of a given volume of that substance, compared with an equal volume of some other substance which is taken as a standard. The standard usually used is water and its specific gravity is called one.

The specific gravity of milk varies according to its solid content and also according to its temperature. Milk is slightly heavier than water and the density of pure milk is supposed to cover a range of

[29] Soldner, Dr. Friedrich, Die Salze der Milch und ihre Beziehungen zu dem Verhalten des Kaseins. Landwirtschaftliche Versuchs Stationen. Vol. 35-36, 1888-1889.

1.029 to 1.034, the average being about 1.032. Pure milk may go above or below these limits but it will seldom do so. The higher the temperature of milk the less its density, and vice versa the lower the temperature the greater its density. For this reason it is necessary to state the temperature at which specific gravity readings are taken and instruments used for determining the specific gravity of milk are used at a temperature of 60° F. (15.5° + C.).

Specific heat.—The specific heat of a substance is the amount of heat required to raise the temperature of a given mass of the substance one degree, compared with the amount of heat required to raise an equal mass of some substance one degree, which is taken as a standard. Water is taken as a standard and its specific heat is called one, and the specific heat of water is higher than for most other substances. The specific heat of milk depends on its solid contents and on its temperature.

The following table taken from the work of Hammer and Johnson [30] gives the specific heat of milk and some milk derivatives. In this work the fat content of the whole milk varied from 3.4 to 4.9 per cent fat; most of it being around 4.3 per cent fat.

Table 26.—Specific Heat of Milk and Milk Derivatives at Different Temperatures. Figures in Parentheses Obtained by Extrapolation.

	0° C. (32° F.)	15° C. (59° F.)	40° C. (104° F.)	60° C. (140° F.)
Whey	0.978	0.976	0.974	0.972
Skimmilk	0.940	0.943	0.952	0.963
Whole milk	0.920	0.938	0.930	0.918
15% cream	0.750	0.923	0.899	0.900
20% cream	0.723	0.940	0.880	0.886
30% cream	0.673	0.983	0.852	0.860
45% cream	0.606	1.016	0.787	0.793
60% cream	0.560	1.053	0.721	0.737
Butter	(0.512)	(0.527)	0.556	0.580

Freezing point.—Since the density of milk is higher than that of water, its freezing point is lower. The freezing point of milk is usually given as nearly 31° F. (—.55° C.), but the variation in the solid content of milk causes the freezing point to vary, between 29° F. (—1.6° C.) and 31° F. (—.55° C.). The more water there is in milk the more nearly the freezing point of milk approaches

[30] Hammer, B. W., and Johnson, A. R., Iowa Exp. Sta., Research Bul. No. 14.

that of water. On this account the freezing point of milk is taken as an index of added water and the instrument most commonly used to determine the freezing point of water is Hortvet's Cryoscope. With this instrument it is stated that as low as 3 per cent added water can be detected in milk.

Refractive index.—When light passes from one medium to another it is deflected in its course at the plane separating the media. This is called refraction and the angle which the deflected ray of light makes with the normal ray at the surface of the medium is called the angle of refraction. Naturally the more dense the medium the greater the angle of refraction and this fact is utilized in detecting added water to milk. There are different instruments used for measuring the angle of refraction and the one most commonly used in milk analysis is the Leiss Immersion Refractometer. In using this instrument it is immersed in the milk and the refraction is read on an arbitrary scale, the reading for average milk being close to 40. Since the density of milk is greater than that of water it naturally has a higher refractive index and adding water to milk reduces the refractive index. By comparing the reading with tables which have been worked out, the per cent of water added to milk can be closely determined. Since temperature affects the density of milk, the temperature must always be taken account of in using the immersion refractometer.

Viscosity of milk and cream.—Viscosity or stickiness is a well-known characteristic of milk and cream and also of some manufactured dairy products. It is important commercially because in the public mind viscosity is closely associated with the presence or absence of a high solid content, especially with milk fat. This is particularly true of market cream, which to give satisfaction on the market must be viscous. However, lack of viscosity does not necessarily mean that dairy products are low in fat content. The process of pasteurization will reduce the viscosity of milk and cream the same as it does that of most other viscous materials and from this standpoint, pasteurization is decidedly objectionable. The viscosity can be at best partially restored by ageing the product and holding it at low temperatures. According to Babcock and Russell [31] the viscosity of milk and cream is due to two factors, first the effect

[31] Babcock, S. M., and Russell, H. L., Wis. Agr. Exp. Sta., Report 1896.

of the solids in solution and second the effect of solids in suspension. Of the latter cause they believe that casein exerts the greatest influence in rendering milk viscous, while fat is the chief factor in causing viscosity of cream.

Madella [32] used a Pagliani Viscometer in studying the viscosity of milk and concluded that there was a direct relation between the coefficient of viscosity and the percentage constituents of the milk. C. Cavazzani [33] using a Kohler Viscometer studied the relative viscosity of cow, goat, and human milk, using respectively 7, 3, and 15 individuals. In this work he compared the length of time required to empty the viscometer of water with the time required to empty the viscometer of milk. The results were as follows:

Table 27.—Relative Viscosity of Cows, Goats, and Human Milk.

Cows' milk	1: 1.67 to 1: 2.03
Goats' milk	1: 2.01 to 1: 2.15
Human milk	1: 1.41 to 1: 2.56

According to Bowen [34] the viscosity of milk at 86° F. is 1.7 times as great as that of water, and at 32° F. the viscosity is 2.4 times that of water. Bowen also states that with a lowering of the temperature of milk its cohesion increases in proportion to its viscosity.

Coefficient of expansion.—Milk and cream like most other substances expand when heated and contract when cooled. This change in volume under the influence of heat is called the coefficient of expansion. Milk and cream which are bottled when cold, will ooze out around the bottle cap if the temperature is allowed to rise. This makes an unsightly package and also, by furnishing a moist surface, makes the collection of dust on the bottle cap more easily possible. The milk also furnishes a good food for bacteria and so increases the chance of contamination when the bottle is opened for use.

The following table compiled from the work of Bowen [35] gives the coefficient of expansion of milk and cream of different percentages of fat at different temperatures. In this work 68° F. was used as a temperature base and the unit 1.000 as a volume base and all changes in volume were reckoned from these two points.

[32] Madella, C., Staz. Sper. Agr. Ital. 37. Reported in Exp. Sta. Rec. XVI.
[33] Cavazzani, C., Zeulbl. Physiol. 18, No. 26. Reported in Exp. Sta. Rec. XVI.
[34] Bowen, John T., The Application of Refrigeration to the Handling of Milk, Bul. 98, U. S. Dept. of Agr.
[35] Bowen, John T. (*loc. cit.*).

Table 28.—Coefficient of Expansion of Milk and Cream of Different Percentages of Fat, at Different Temperatures.

Per Cent Fat	50° F. (10° C.)	60° F. (15.5° C.)	70° F. (21.1° C.)	100° F. (37.7° C.)	120° F. (48.8° C.)	130° F. (54.4° C.)	140° F. (60° C.)
1.....	.9980	.9990	1.000	1.0060	1.0110	1.0140	1.0175
3.....	.9975	.9990	1.000	1.0065	1.0115	1.0140	1.0175
4.....	.9975	.9985	1.000	1.0065	1.0115	1.0140	1.0175
5.....	.9975	.9985	1.000	1.0065	1.0115	1.0140	1.0175
20.....	.9930	.9975	1.0005	1.0100	1.0155	1.0180	1.0205
30.....	.9915	.9965	1.0010	1.0130	1.0195	1.0220	1.0250
40.....	.9890	.9950	1.0010	1.0165	1.0235	1.0265	1.0290

Electrical conductivity.—Milk is not a good conductor of an electric current, and what ability it has as an electrical conductor seems to be due to its mineral content. There is no constant relation between the specific gravity of milk and its resistance to an electric current. The resistance of milk is not constant and is said to vary all the way from 180 to 310 ohms.

Adding water to milk increases its resistance and for this reason attempts have been made to utilize the electric current in detecting added water in milk. Since, however, the mineral content of water varies so widely, very little dependence can be placed on the results, especially from a quantitative standpoint. Several attempts have been made to utilize the electric current in destroying germs in milk, the idea being to actually electrocute the bacteria. While it was found that milk through which an electric current had been passed contained fewer bacteria than it did before treatment, it was also found that the reduction in bacteria was due to the heat generated, because of the high resistance of milk to an electrical current. The process was simply one of pasteurization. When this fact became known claims were made, that since the heat was generated by resistance to the electrical current, each particle (molecule) of milk was actually raised to the desired temperature in a few seconds and that therefore this method of heating milk was superior to others. This claim has, however, never been proven.

Chapter IV

MICROBIOLOGY AS APPLIED TO MARKET MILK

Bacteria are small plants which exist nearly everywhere in nature. They are so small that it requires a microscope which will magnify about 1,200 times in order to see them and study them successfully. They vary in size from approximately 0.5-8 microns in length and 0.2-1 microns in diameter (a micron is 1/1,000 mm. or about 1/25,000 inches).

Bacteria are identified in many different ways and one of these ways is by their form or shape. In general there are three main forms, the rods, the cocci or round forms, and the spirilli or bent rods. The bent rods are sometimes referred to as cork-screw shaped. Some bacteria are motile—they have the power of moving about in the fluid in which they are suspended and they do this by means of hair-like appendages called flagella or cilia. Certain species of bacteria require oxygen (air) for growth, while others cannot grow in oxygen (air). The former are called aerobes and the latter are called anaerobes. Still others which can grow in either the presence or absence of oxygen are called facultative. A facultative aerobe is an organism (anaerobe) which normally grows without oxygen, but which can grow where there is oxygen. A facultative anaerobe is an organism (aerobe) which normally grows in the presence of oxygen, but can adapt itself to conditions where there is no oxygen.

Another method of classifying bacteria is dependent on the fact as to whether or not they produce disease. Those which do produce disease are called pathogenic, while the non-disease producing ones are called non-pathogenic. There are organisms which are hard to classify in regard to their ability to produce or not to produce disease. Good examples of this kind are the so-called putrefactive types, which are sometimes found in milk. While these organisms

may not affect adults, they might be harmful to infants and young children.

Bacteria are still farther classified by their action on different kinds of media in which they are growing and the products which they produce in them. Milk is a very common medium used for identifying bacteria. Three of the most common products of bacterial action are acid, gas, and enzymes of different kinds, and the presence of these substances is quite apparent in milk, due to their action on the milk casein.

One very important means of differentiation of species of bacteria is the ability of some organisms to form spores. The spore stage in the life of an organism is sometimes referred to as the seed stage and its function seems to be to enable the organism to withstand unfavorable conditions, such as extreme temperatures, of both heat and cold. Cases are on record where spores have withstood boiling temperature for several hours.

In the process of spore formation the protoplasm of the cell becomes granular and these granules finally coalesce to form the spore. The location of the spore within the cell is variable with different species but is quite constant with each spore forming organism, and this is an aid in identifying organisms. Sometimes the spore is in the end, sometimes in the center and sometimes part way between the end and the center of the cell.

There are several conditions which are necessary for the growth and reproduction of bacteria. One of the most important is the presence of moisture. Some one has stated that bacteria must have at least 30 per cent moisture in the medium in order to grow and develop, and while this figure is very uncertain it gives some idea of moisture requirements of microörganisms. The medium must contain organic material and also mineral matter and generally speaking bacteria thrive better in an alkaline than in an acid medium. The influence of oxygen on bacterial growth has already been discussed.

Proper temperature is necessary for bacterial growth. There is a wide range of optimum temperatures for different species, but most organisms grow best at a temperature from 20° C. to 42° C. (68° F.-107.6° F.). There are, however, many exceptions to the above-mentioned temperatures. Certain species of bacteria, called

thermophiles, will grow at 70° C.-80° C. (158° F.-176° F.) while others grow in ice cream, which is around 0°.

Bacteria are destroyed by two methods: heat and chemicals. Chemicals are used in some cases, where the main object in view is the destruction of the organism, without any reference to the effect on the object being treated. In the sterilization of foods, however, chemicals would render the foods undesirable or spoil them entirely. The same is true of utensils which are to be used as food containers, such as milk cans, bottles, etc.

In some instances chemicals are added to substances to inhibit the growth of bacteria rather than to actually kill them.

Heat is probably one of the most effective and useful methods of killing bacteria, and this is especially true of live steam, which is much more effective than dry heat. In sterilizing objects by means of heat, the time involved is an important factor. Bacteria which will survive certain temperatures for a short time will be destroyed by this same temperature if the heat is applied long enough. This fact is utilized in destroying bacteria in food products. Cold cannot be depended upon to kill germ life, although certain species of organisms will die if exposed to low temperatures for a long time. Low temperatures are mainly useful in preventing germ growth.

Bacteria reproduce by fission. When the cell has matured, a slight indentation appears on each side of the organism and this indentation gradually increases until the organism breaks in two. Cell walls form at the place where the stricture appeared in the original organism, to form the ends of the two new organisms.

Some species of bacteria reproduce very rapidly, reproduction taking place as frequently as every 20 or 30 minutes, so that in a short time large numbers of organisms may be present, all descendants from one single cell. The rapid reproduction mentioned above will not take place indefinitely as the products produced by the bacteria become harmful to themselves and will retard their multiplication.

Since bacteria are present almost everywhere in nature, it naturally is easy for them to get into milk. For the same reason it is true that there is a possibility of all kinds of bacteria being found in milk, and this may include pathogenic organisms from the cow or from persons handling the milk who are infected with diseases of

various kinds. Most bacteria multiply in milk although all of them do not do so. The most notable example of this kind is bacterium tuberculosis, which while it will live in milk will not multiply there.

It can be seen from the above statements that the flora of milk will depend largely on the circumstances and environment under which it is produced and handled. One of the reasons why milk is, comparatively speaking, so seldom a medium for the transmission of disease is because the rules and regulations governing its production and handling are such as to minimize such a possibility. However, despite the general distribution of bacteria in nature and the different environment under which milk is handled, it has quite a definite flora.

GERM CONTENT OF THE UDDER

Milk as it is drawn from the healthy udder of the cow is not sterile as was once commonly supposed. The numbers of bacteria existing in the udder are small and have little effect on the numbers per c.c. in the milk, except in cases where the object is to produce milk of extremely low germ content, as in the case of certified milk. Harding and Wilson [36] examined 1,230 samples of milk from 78 cows and found the average bacterial count to be 428 bacteria per c.c. There was no uniformity in the numbers of organisms found in different quarters of the same udder, although the back quarters contained about three times the bacteria that were found in the front quarters. No explanation could be made for this. While the bacteria from 900 of the samples examined fell into 71 groups, the predominating types were micrococci.

As indicated above if milk of extremely low germ content is desired the bacterial content of the udder must be taken into account, because the germ content of the udder of some cows is normally high, while the germ content of the udders of other cows is normally low. This fact is shown by the data in the following table.[37]

The data in Table 29 needs little comment. It will be seen that certain cows showed normally a high count in the udder, while others normally gave milk of a low count, and this was true with

[36] Harding, H. A., and Wilson, J. K., A Study of the Udder Flora of Cows, Technical Bulletin No. 27, N. Y. State Exp. Station, Geneva, N. Y.

[37] From unpublished data collected by the author.

Table 29.—Bacteria per cc. in Milk from Udders of Six Different Cows.

Milker Number	Cow Number I	II	III	IV	V	VI
1	115	55	185	2400	340	355
2	87	55	115	785	385	605
3	45	94	130	1115	7100	205
4	115	125	233	770	3172	475
5	36	63	85	1120	120	277
6	31	13	25	490	340	140
7	465	65	271	1300	13100	27200
8	270	70	290	757	2600	1772
9	130	120	995	2190	1155	800
10	127	83	270	10350	1250	303
11	62	75	143	2320	1305	355
12	54	134	39	3650	570	1497
13	100	40	135	1132	335	275
14	42	134	70	1480	1750	135
15	190	115	116	595	425	110
16	49	38	16	14000	385	585

16 different milkers. This fact is especially well brought out by comparing cows 1 and 4. The period over which this data was collected was about six weeks, and no attempt was made to classify the types of bacteria.

LACTIC ACID BACTERIA

Probably the most common type of bacteria found in milk is the Bact. lactis acidi group. These bacteria are responsible for the souring of milk, and many different kinds of lactic acid producing organisms have been studied and classified. The changes which these organisms produce in milk are referred to as lactic fermentations. The lactic acid bacteria grow in milk more rapidly than most other kinds, as they have quite an optimum range of temperatures. The acid medium, however, soon becomes unfavorable to them and after about 0.7 per cent of acid has developed they will cease to grow. The Bact. lactis acidi group are opposed to the putrefactive types and will for a long time prevent the growth and in some cases destroy the putrefactive types of bacteria. In one sense the lactic acid bacteria are considered useful in determining whether market milk is fit to be used. The acid produced by them is an indication either of the age of the milk or of the sanitary conditions under which the milk has been produced or handled.

PUTREFACTIVE BACTERIA

This class of organisms is directly opposed to the lactic acid types. It comprises nearly all kinds of bacteria so far as morphology is concerned. This group of organisms attacks the proteid compounds of milk and splits them up or, as it is commonly expressed, digests them. For this reason they are sometimes referred to as the casein digesting bacteria or peptonizing bacteria.

For several reasons these organisms are very undesirable in milk. They usually produce gas and probably other products which cause digestive disorders, especially among infants. They furthermore are indicative of unsanitary methods of milk production or handling or both, and sanitarians regard their presence as strongly indicative of the fact that filthy material has come in contact with the milk. Sometimes peptonizing bacteria will be present in milk in large numbers and their presence in milk will be undetected by flavor and odor. At other times they will peptonize milk with the production of strong and disagreeable odors and many of the so-called "off flavors" of milk are probably due to this class of organisms.

ROPY MILK

One quite common trouble experienced by milk men is ropy or slimy milk. In a well-developed case of this kind milk will string out several feet when an object such as a spoon is inserted into it and then raised above the vessel containing the milk. This trouble is caused by certain groups of organisms of which B. lactis viscosus is one of the best known. This organism is most frequently found in water, especially stagnant water, and if cows wade in pools where this organism exists, the exterior of their udders becomes contaminated with it and so it finds its way into the milk pail. Sometimes B. lactis viscosus is found in pools in milk stations and when the cans of milk are placed in the pools a drop of water will spatter into the can and thus will contaminate it. The sliminess of the organism is said to be due to a capsule which surrounds it, and the presence of this capsule makes the germ quite resistant to temperatures commonly used in sterilizing dairy utensils. This makes the organism quite difficult to get rid of when once it gets into a milk supply. So far as can be ascertained slimy or ropy milk is

perfectly harmless so far as producing disease is concerned. It is, however, so disagreeable that no one will use the milk when it is in this condition.

SWEET CURDLING

Sweet curdling of milk is due to the presence of two enzymes, rennet and trypsin, which are produced by certain groups of bacteria. The rennet is said to act first and, as in the case of adding rennet to milk in cheese making, the casein is precipitated. This occurs without large amounts of acid being present, hence the name of sweet curdling. After the casein is precipitated by the rennet, the trypsin begins to act and this digests the curd until the casein is dissolved and the mass of milk liquified.

COLORED MILK

Certain bacteria, called chromogens, have the power of producing pigments and when these organisms get into milk the pigments produced will color it. One of the most common cases of coloring in milk is red milk said to be produced by B. prodigiosus. The coloring in milk produced by this organism is sometimes confused with bloody milk, caused by the rupture of a blood vessel in the udder. Bloody milk sometimes accompanies garget of the udder. Another organism, B. erythrogens, also colors milk red.

Blue milk has been recognized for many years and this color is due to the organism B. cyanogens. This organism grows very slowly and the blue color will usually not become apparent until the milk is two or three days old.

Hammer [38] was able to isolate B. cyanogens from a sample of market milk which showed a blue color, and which had turned sour when the organism was isolated from it. He was able to reproduce the blue color in raw, pasteurized and sterilized milk, by inoculating them with cultures of B. cyanogens taken from the original sample of market milk. Increased acidity intensified the blue color.

Hammer [39] studied and described two organisms which produce a yellow pigment in milk. These he named respectively B. synxanthus and B. aurantiacus.

[38] Hammer, B. W., A Bacteriological Study of Blue Milk, Iowa Research Bull. No. 15.
[39] Hammer, B. W., Bacteriological Studies on Two Yellow Milk Organisms, Iowa Research Bull. No. 20.

Milk colored by pigments from bacterial action is, comparatively speaking, quite rare. One probable reason for this is because the lactic acid bacteria soon gain the ascendancy over the organisms producing the pigments and either inhibit their growth or destroy them entirely.

BITTER MILK

The cause of bitter milk has in some instances been traced to bacteria. The organisms producing this bitter flavor seem to be those which grow at low temperatures and this fact is recognized by dairymen in making starters. The organisms causing this trouble grow very slowly as bitter flavors frequently develop in milk which has been held for a long time. The substance which actually produces the bitter flavor is unknown.

PATHOGENIC BACTERIA

Disease-producing organisms sometimes get into milk and many cases are on record where germs carried in milk have produced epidemics. Diseases transmitted in this way are spoken of as milk-borne diseases. Among the most common are diphtheria, typhoid, tuberculosis and scarlet fever, although the specific cause of the latter disease has never been determined. Data is on record which seems to prove that septic sore throat can also be transmitted by means of milk. The germ causing any specific disease may get into milk from persons suffering with the disease, or from the hands or clothing of people who have been in contact with individuals suffering with the disease. Milk utensils such as milk bottles which have been in sick rooms might also cause epidemics, unless thoroughly washed and sterilized before milk is placed in them. Cows which are infected with disease may transmit it through their milk, and this is true of tuberculosis. There seems to be abundant proof that bovine tuberculosis may be transmitted to human beings, especially infants and children.

INERT BACTERIA

There are sometimes present in milk, bacteria which are called inert because they have no effect on the milk in any way. This group of organisms does not multiply rapidly in milk and usually it is overcome by the other types present.

YEASTS AND MOLDS

Yeasts and molds are also found in milk, but they do not play as important a part in the changes occurring in milk as do the bacteria. Yeasts and molds, like bacteria, are widely distributed in nature. The yeasts are microscopic plants but are usually larger than bacteria and generally speaking they thrive better in a medium which has only a small amount of acid or is slightly alkaline. Yeast cells are usually from 2.5 to 12 microns in size. Yeasts differ mainly from bacteria in their mode of reproduction which is by budding. A bud appears on the side of the mother cell and this bud gradually increases in size until it is as large as the parent cell. The young cell may not at once become detached from the parent cell and thus masses of yeast cells form, although eventually they will become more or less separated.

One main difference between bacteria and yeasts is that the latter produce alcoholic fermentation whereas the bacteria as a rule do not.

The molds are much more complex in structure than either the yeasts or bacteria. They grow in thread-like masses, each thread being called a hypha, and a mass of hyphæ is called a mycelium. The methods of reproduction of molds vary with different species, but usually the mycelium branches and on the ends of these branches spores form which are reproductive bodies. These spores are formed in different ways in different species of molds, and the method of spore formation is one of the means used to classify molds.

Molds are of importance in manufacturing some of the soft cheeses, but their chief significance in milk is to indicate that the product is old and has been exposed to unsanitary conditions.

CELLS IN MILK

Since the udder of the cow is a true organ of secretion and is very active during the period of lactation, it is only natural to expect that epitheleal cells would be found in milk.

Leucocytes, normally found in the blood, are also found in milk, sometimes in large numbers. Just how the leucocytes enter milk has never been fully settled. When leucocytes were first noticed in milk it caused a great deal of consternation among those who had control of milk supplies. A puss cell is a dead leucocyte and since it was

difficult to distinguish, under the microscope, the difference between a dead and a live leucocyte, sanitarians were fearful that pus cells were present. Furthermore, in cases of suppuration leucocytes are very abundant at the point where the suppuration occurs, as they act as scavengers in carrying off the products of disease. In view of this fact leucocytes in milk might indicate feverish conditions of the udder, and some milk inspectors proceeded to condemn milk supplies on a basis of their cell content. The subject was studied by several investigators and all found that the presence of leucocytes in milk was apparently a perfectly normal function of milk production. The following table [40] shows the variation in the cell content of milk from 27 different cows, selected from several different herds. It will be seen by examining this table that the cell content of the milk from these animals varied all the way from 4000 per c.c. to over 5,576,000 per c.c.

Table 30.—Cell Content of Milk per Cubic Centimeter from 27 Different Cows.

Cow No.	Number of Cells per Cubic Centimeter	Cow No.	Number of Cells per Cubic Centimeter
1	283,000	15	121,500
2	654,000	16	17,600
3	197,500	17	29,000
4	1,972,500	18	143,000
5	3,576,000	19	135,650
6	426,000	20	55,000
7	258,500	21	18,000
8	644,000	22	3,064,000
9	676,500	23	207,000
10	2,487,500	24	184,000
11	524,000	25	455,000
12	20,000	26	228,000
13	956,000	27	4,000
14	1,321,500		

So far as could be determined the cows were perfectly normal in every way, and while not shown in this table the same series of investigations showed that certain animals normally produced milk of a high-cell content, while others normally produced milk of a low-cell content.

While this subject has received considerable attention, the exact significance of leucocytes in milk has never been determined and

[40] Ross, H. E., The Cell Content of Milk, Cornell University Experiment Station, Bull. No. 303.

none of the investigators of the subject have been willing to fix limits for the number of cells per c.c. which should be allowed in market milk. It is true that udder disturbances are almost always accompanied by a high leucocyte content, yet in some cases equally high counts occur in milk which is apparently normal. So far as is known no harmful effects have ever been produced by using normal milk which contained a high cell content per c.c.

GERMICIDAL ACTION OF MILK

It has been noted that in some cases bacteria in freshly drawn milk will for a time apparently decrease in numbers. The reason for this has never been determined, some attributing it to a germicidal property of the milk, others to the fact that certain strains of bacteria do not find milk a suitable medium in which to grow and so gradually die off. Another theory advanced by some investigators is that the bacteria do not die off but that agglutination takes place.

The following table from the work of Hunziker [41] shows the effect of germicidal action.

Table 31.—Bacteria per c.c. in Same Sample of Milk Held at Different Temperatures, for Different Periods of Time.

Temperature	Cow-Warm	After 2½ Hours	After 5 Hours	After 7½ Hours	After 10 Hours
40° F.....	2214	2154	2020	2074	2180
70° F.....	2214	2080	1874	4346	142,000
97° F.....	2214	2246	6240	530,000	1,148,000

Stocking [42] after investigating the subject concluded that milk did not possess germicidal properties, but that certain bacteria found the milk an unsuitable medium and therefore died off.

Sherman and Curran [43] inoculated fresh samples of aseptically drawn milk with cultures of streptococcus lactis. They concluded from the results obtained that freshly drawn milk had a slight but nevertheless definite inhibitory effect on the growth of the particular organism with which they were working.

[41] Hunziker, O. F., Investigations Concerning the Germicidal Action in Cows' Milk, Cornell Univ. Bull. 197.

[42] Stocking, W. A., Germicidal Action in Cows' Milk, Storrs Exp. Sta. Report, 1904.

[43] Sherman, J. M., and Curran, H. R., Proceedings of Society for Exp. Biology & Medicine, Vol. 22, 1924.

The consensus of opinion in regard to this subject may be summed up as follows:

1. That cows' milk, when freshly drawn, has germicidal or at least inhibitory properties.

2. That the germicidal or inhibitory property is specific for certain organisms and certain cows. This is mentioned by Hunziker and also by Roseneau and McCoy [44] and Chambers.[45]

3. That the germicidal property of milk is marked in warm milk (37° C.) and less marked in cold milk (4.4° C.).

4. That a temperature of 80° C. (176° F.) applied for a short time will destroy the germicidal property of milk.

[44] Roseneau, M. J., and McCoy, G. W., Milk and its Relation to the Public Health, U. S. Hygienic Laboratory.

[45] Chambers, W. H., Bacterial Inhibition, Journal of Bacteriology, Vol. V.

Chapter V

THE CHEMICAL EXAMINATION OF MARKET MILK

The examination of market milk falls naturally into two divisions —examination for chemical composition, and examination for bacteria. On account of the time and expense involved each one of these examinations should be made as simple as possible and still have them give enough facts to make them of use to those who have control of the milk supply.

The chemical examination of market milk usually consists in a determination of the percentage of fat by the Babcock method, a determination of the solids not fat by the specific gravity method and a determination of the percentage of acid. Also, there are sometimes carried out a few simple tests for some of the more common preservatives which might be used fraudulently to keep milk from spoiling.

THE BABCOCK TEST FOR FAT IN MILK

The Babcock test is a test for the percentage of fat in milk and its products. The test may be accurately performed by one who has had a moderate amount of training provided the operator uses careful methods but the simplicity of the method sometimes leads the one performing the test to become careless and inaccurate results are obtained.

Preparation of the sample.—Inaccurate sampling and careless preparation of samples probably cause more errors in determining the percentage of fat in milk than do errors in the performance of the test itself. In taking a sample from a can or vat, the milk should be thoroughly stirred and if the amount to be sampled is small enough it is best to pour the milk from one vessel to another. If the milk to be tested is taken from a bottle as in the case of a composite sample which has been preserved, it may be necessary to warm the

FIG. 1. Steam Turbine Centrifuges used in the Babcock Test.

sample to not over 95° F. and mix it with a small brush. This will apply especially to cream samples.

Testing whole milk.—The amount of milk used is 17.6 c.c. and it is measured by means of a pipette having on it only one graduation. The 17.6 c.c. pipette will deliver into the test bottle 18 grams of normal milk and the whole milk test bottle will give readings in terms of percentage only when 18 grams of milk are used. The pipette is placed in the mouth and by suction the milk is drawn above the graduated mark, care being taken not to draw any into the mouth. The index finger is then placed over the end of the pipette and by carefully releasing the pressure of the index finger the column of milk is allowed to settle to the 17.6 c.c. mark on the pipette. Have the index finger dry and the mark on the pipette on a level with the eye. The milk is then placed in the test bottle by inserting the point of the pipette into the top of the test bottle and gradually removing the index finger from the pipette. In order to allow the air to escape from the test bottle, and thus avoid spilling the sample, the pipette should be held as vertically as possible and the test bottle as horizontally as possible.

Whole milk test bottles are usually of two types, one graduated as high as ten per cent and having each mark on the bottle equal to 0.1 of one per cent, while the second type is graduated as high as eight per cent and each mark on the bottle has a value equal to 0.05 of one per cent. The latter allow of more accurate readings. Samples should always be tested in duplicate as one is a check on the other and if the readings agree the operator is reasonably sure that the work has been accurately performed. 17.5 c.c. of sulphuric acid of a sp. gr. of 1.82 to 1.83 are then added from a special measure having only the one graduation. The test bottle is revolved as the acid is poured into it, in order to rinse all milk from the neck of the bottle into the body of the bottle. The sulphuric acid destroys by moist combustion all of the milk solids excepting the fat and great pains should be taken to thoroughly mix the contents of the bottle as soon as the acid is poured into it.

After mixing the contents of the bottle it is best not to let the samples stand over 30 minutes before completing the test. The sample is then whirled in a special centrifuge and since the machine runs at a high rate of speed it is necessary to have the machine

balanced—for every bottle on one side of the machine there should be one of equal weight directly opposite it. Babcock centrifuges are run by hand, steam and electrical power and to do the best work it is essential to have some method of keeping the machine hot. With the steam centrifuge it is easy to do this but in case of the hand machine it is necessary to fill it with hot water to the bottom of the bottle cups, and the better types of electric Babcock centrifuges are provided with a resistance coil placed in the bottom of the machine for maintaining a sufficiently high temperature.

The bottles are whirled for five minutes and hot water is then added until the contents of the bottles are brought to the base of the bottle neck. Whirling is then continued for two minutes and hot water is again added until the fat column is well within the graduated part of the bottle neck. The bottles are then whirled to bring all of the fat within the graduated part of the bottle neck. The samples should be read while they are hot, care being taken to hold the fat column on a level with the eye. In reading whole milk bottles the reading should be taken between the extreme points of the menisci on the fat column and usually this is made easier by employing a set of calipers.

Testing cream for fat.—Cream is so variable in composition and is so viscous that the correct amount for testing cannot be measured but must be weighed instead, and different types of scales have been designed for the purpose. Cream sometimes contains over 50 per cent fat, and 40 per cent fat in cream is very common. To hold the fat from 18 grams of such rich cream would require a test bottle with a large neck. Test bottles with necks of large diameter are objectionable because of the liability of error in reading them and while test bottles with long narrow necks are useful so far as reading them is concerned, yet such bottles require a centrifuge of larger diameter than is usually employed. Oftentimes cream bottles with necks of moderate diameter and length are employed and 9 grams of cream instead of 18 are used. The final result is then multiplied by 2 but this method has the objection of doubling any error which might be made in reading.

The best bottles for testing cream are those which are made to read in terms of percentage when 9 grams of the material are used. The best method of weighing the cream into the bottle is to balance

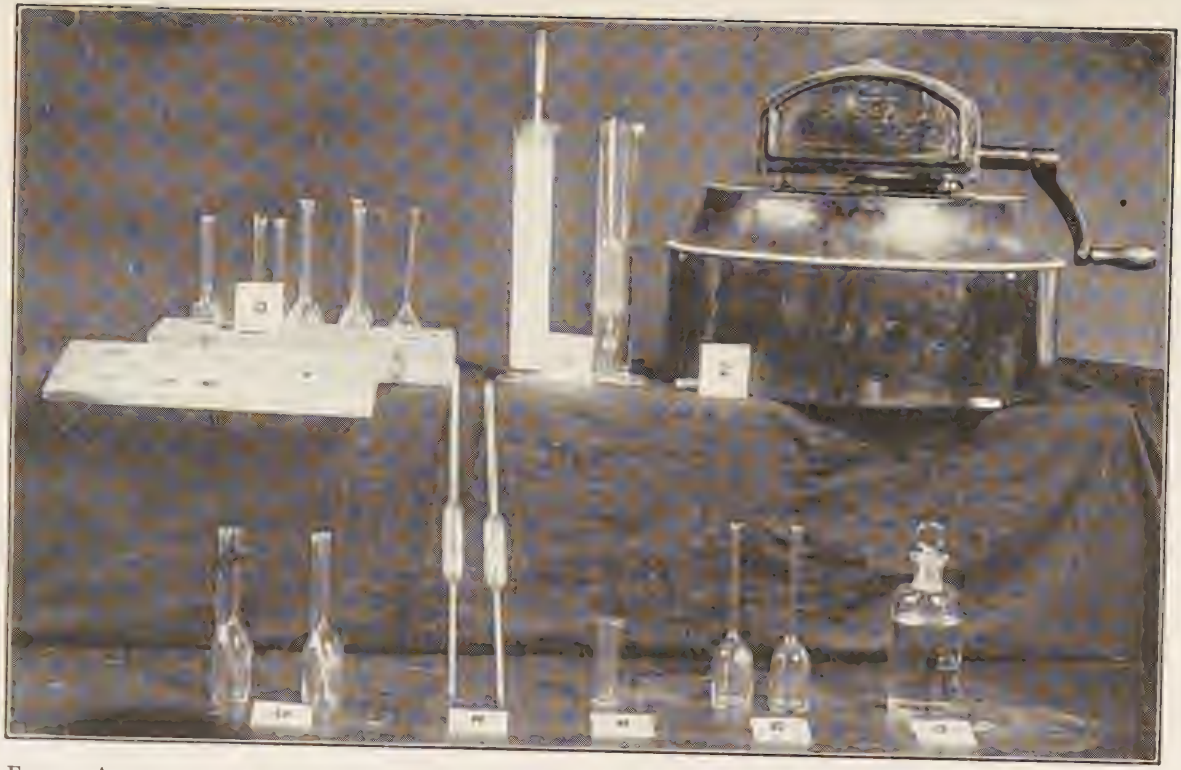

FIG. 2. Apparatus for Testing Milk and Skimmilk for Fat by the Babcock Method and Lactometers for Determining the Specific Gravity of Milk Z, Hand Centrifuge; D, Test Bottle Block Containing Cream, Whole Milk, and Skimmilk Test Bottles; G, Sulphuric Acid; K, 17.5 c.c. Acid Measure; Q, Whole Milk Test Bottles; R, 17.6 c.c. Pipettes; U, Skimmilk Test Bottles; C, Lactometers, Quevenne on Left, Board of Health on Right.

the bottle on the scales. Most scales have a tare weight for this purpose. The proper weight is then placed in the scale pan opposite the test bottle and cream is added to the bottle from a pipette until the scales are balanced. If 9 grams of cream are used it is best to add approximately 9 grams of warm water and then use the normal amount of 17.5 c.c. of sulphuric acid, the same as in testing whole milk.

In adding both the warm water and the acid it should be done

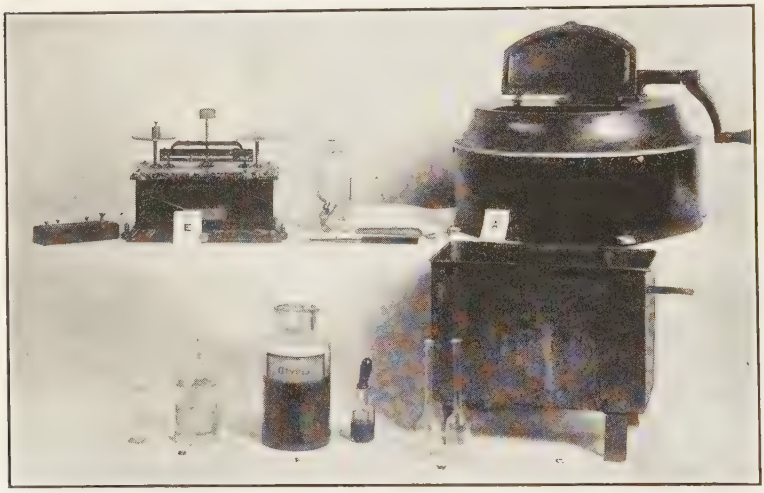

FIG. 3. Apparatus for Testing Cream for Fat by the Babcock Method: A, Hand Centrifuge; B, Sulphuric Acid and 17.5 c.c. Acid Measure; C, Tank for Tempering the Fat in the Test Bottles; E, Balances for Weighing Cream Samples; P, Glymol for Removing the Meniscus from the Fat Column; W, Cream Test Bottles; Sample Jar for Holding Milk and Cream for Testing, Especially Composite Samples.

in such a way as to rinse into the body of the bottle all of the cream which adhered to the neck of the bottle. The bottle should be shaken until all of its contents are dissolved and they are then placed in the centrifuge and whirled for five minutes. The machine is then stopped and the bottles filled to the base of the neck with hot water. Whirling is continued for two minutes and the bottles are then filled so that the fat column is within the graduated part of the bottle neck. A whirling for one minute is then given to collect all of the fat in the neck of the bottle. So large a column

of fat as is contained in the neck of a cream bottle is greatly affected by temperature. On this account the cream bottles should be placed in a water bath to temper the fat column. The water should be maintained at a temperature of 140° F. and care should be taken to have the water level slightly above the fat column. The bottles should remain in this tempering bath not less than three minutes and a few drops of miniscus remover is then added to the top of the fat column so that the fat column will be level and thus make an accurate reading possible. For this purpose Glymol or white mineral oil is recommended, although a good grade of light separator oil of the proper density will answer the purpose equally well.

In order to show a sharper line of demarkation between the fat column and the miniscus remover, the latter should be colored red with alkana root, which is an oil soluble vegetable substance and which can be obtained from most drug supply houses. Reading the cream bottle should be done as quickly as possible, as the cream column cools and therefore settles very rapidly, thus making incorrect readings easily possible.

Babcock test bottles of all kinds should be emptied as soon as possible after reading, as this makes them easier to clean. They should be washed in some washing powder solution and then thoroughly rinsed.

DENSITY OF MILK AND THE USE OF THE LACTOMETER

A determination of the density or specific gravity of milk is essential because it helps to determine whether anything has been added to milk or anything taken away from it. The specific gravity of milk is usually determined by means of a special hydrometer called a lactometer. There are two kinds of lactometers in common use, one called the Quevenne and the other the New York State Board of Health.

The Quevenne lactometer consists of a long narrow glass stem on which are the lactometer graduations, and usually the instrument is graduated from 15 to 45 lactometer degrees. Below the lactometer scale there is, on the better grade of lactometers, a thermometer scale the bulb of which is in the bottom of the instrument. Below the graduated stem the instrument is enlarged into a hollow glass

chamber, the purpose of which is to give buoyancy when placed in a liquid. In the lower end of the lactometer is placed shot or mercury to cause the instrument to stand upright when in use. True specific gravity readings may be obtained from a Quevenne lactometer reading by prefixing 1.0 before the lactometer reading. Thus a Quevenne lactometer reading of 32 would correspond to a specific gravity reading of 1.032.

The New York State Board of Health Lactometer is similar to the Quevenne in shape but the graduations are larger, the instrument usually being graduated from 0 to 120 lactometer degrees.

With reference to the Quevenne lactometer, the Board of Health lactometer is so graduated that a reading of 100 Board of Health corresponds to a reading of 29 Quevenne or, in other words, one degree Board of Health reading is equivalent to .29 of a degree Quevenne reading. To convert Quevenne readings to Board of Health readings it would therefore be necessary to divide the Quevenne reading by .29. On the other hand, to convert Board of Health lactometer readings to Quevenne readings the former should be multiplied by .29. Pure milk is not supposed to give a reading of less than 29 degrees Quevenne or 100 degrees Board of Health, and the Quevenne reading of average milk is 32, which is equivalent to a Board of Health reading of 110.3.

The density of milk, like that of other fluids, is affected by temperature and for that reason lactometers are graduated to give correct readings when the milk is at a temperature of 60° F. If milk is other than 60° F. at the time the reading is made a correction for temperature must be made. In case of the Quevenne lactometer the correction factor is 0.1 of a lactometer degree for every degree of temperature which the milk is above or below 60° F., and in case of the Board of Health lactometer the correction is 0.3 of a lactometer degree for every degree in temperature which the milk is above or below 60° F. The lower the temperature of milk the greater its density and the higher the temperature of milk the less its density. For these reasons when the temperature of milk is about 60° F. the correction factor is added to the reading indicated by the lactometer and vice versa when the temperature of the milk is below 60° F. the correction factor is subtracted from

the reading indicated by the lactometer. (For illustrative examples see Chapter 21.)

Since the density of water is less than that of milk, adding water to milk will lower its specific gravity. It is perfectly obvious that milk may be both skimmed and watered, so that a lactometer reading would indicate perfectly normal milk. In a case of this kind a knowledge of the solids not fat and the total solid content of the milk is necessary in determining whether or not milk has been adulterated, and this knowledge may be determined by certain formulæ in which use is made of the Quevenne lactometer reading and the Babcock test reading. There are several formulæ in use but one devised by Professor H. C. Troy is as accurate as any of the others and is easy to apply. The formula is as follows: $\frac{L + F}{4}$ = solids not fat. In this formula, L stands for the Quevenne lactometer reading and F for the Babcock test reading. Problems illustrating the use of this formula are given in Chapter 21.

It should be borne in mind that Board of Health readings cannot be used in this formula.

The specific gravity of freshly drawn milk cannot be determined with a lactometer. This is because milk recently drawn from the udder contains gases which would give a lower specific gravity to milk than it actually possesses. Milk should be drawn from the udder at least two hours before determining its density with the lactometer. The fact that freshly drawn milk gives a low lactometer reading is referred to as Recknagels' phenomenon.

TESTING FOR THE PERCENTAGE OF ACID IN MILK

Excessive amounts of acid in milk or cream may be detected by the sense of smell or taste. Frequently, however, milk may be approaching a point where its acid content is sufficient to greatly lessen its keeping qualities and yet its condition cannot be detected by either smell or taste. Furthermore, a knowledge of the percentage of acid in milk is of use to the milk inspector in helping to determine the sanitary quality of milk.

A determination of the percentage of acid in milk is based on the chemical principle that equal volumes of acids and alkalies of the

same strength will exactly neutralize one another. The point of neutralization is determined by means of an indicator which gives one color in an alkaline medium and another color in an acid medium. There are many kinds of indicators used in chemistry for different solutions. The one generally used for the determination of the percentage of acid in milk is phenolphthalein which is colorless in an acid medium and pink in an alkaline medium. In finding the percentage of acid in milk it is necessary to know the weight of the milk and the strength of the alkali used. If the specific gravity of the milk to be tested is known, the milk may be measured and the number of cubic centimeters used, multiplied by the specific gravity will give the number of grams taken. The ordinary Babcock pipette is frequently used for this purpose since it delivers 18 grams of whole milk.

The strength of the alkali used to test acidity in milk is given in terms of its normality, and a one-tenth normal alkali (expressed as n/10) is commonly used. 1 c.c. of an n/10 lactic acid solution contains .009 grams of lactic acid. Since equal volumes of acids and alkalies of the same strength exactly neutralize one another, 1 c.c. of n/10 alkali would just neutralize .009 grams of lactic acid. Therefore in order to find the percentage of acid in milk, when an n/10 alkali is used, the number of c.c. of n/10 alkali necessary to neutralize the acid in the grams of milk taken is multiplied by .009. This product is divided by the grams of milk taken and the quotient multiplied by 100. The process may be expressed by the following equation:

$$\frac{\text{c.c. of n/10 alkali} \times .009}{\text{grams of milk}} \times 100 = \text{percentage of acid.}$$

(For illustrative example, see Problem No. 23, Chapter 21.)

The alkali is measured from a glass tube called a burette which should be graduated at least as fine as 1/10 c.c. The bottom of the burette is provided with a pinch-cock or class stop-cock so that the alkali can be allowed to flow into the milk, one drop at a time. The milk is measured or weighed into any convenient dish such as a glass beaker or white cup. After weighing or measuring out the milk it is well to add about an equal amount of water so that when the alkali is added the color change may be more easily detected. Before running in the alkali from the burette three or four drops of the

phenolphthalein are added to the milk and the alkali is added slowly until the milk has a faint, but permanent pink color. As the alkali is added, the beaker or dish containing the milk should be gently shaken or stirred with a glass rod, in order to thoroughly mix the alkali and milk. The permanent pink color which is obtained by completely neutralizing the acid, will soon disappear if the milk is allowed to stand for a short time.

In dairy plants it is sometimes difficult to obtain accurate n/10 alkali solutions and to furnish suitable alkali solutions, tablets have been manufactured, each one containing enough alkali to just neutralize .03492 grams of lactic acid. By dissolving a definite number of these tablets in a given quantity of water (preferably distilled water) the exact strength of the solution may be computed. These tablets are manufactured with the indicator in them. A specific example showing how to compute the strength of alkali tablet solutions is given in Problem No. 24, Chapter 21.

Since in most milk plants the patrons are paid for their milk on a basis of its fat content, it is necessary to test the milk for the percentage of fat. It would be impossible to test the milk for each patron daily and in order to overcome this difficulty there is kept a composite sample of each patron's milk. A composite sample in relation to dairy work is defined as a sample containing an aliquot portion of milk from the same source for several days and to which some preservative has been added. There are several chemicals which have been tried for the purpose of preserving composite samples, but the one which has given the best satisfaction is mercuric chloride ($HgCl_2$) which is commonly known as corrosive sublimate. So general has the use of this chemical for this purpose become that it is now sold by the dairy supply houses in tablet form. Two to four tablets are usually necessary to preserve a composite sample for two weeks.

Composite samples should not be kept for a period longer than 15 days and it is much better to keep them no longer than 10 days. However, most dairy plants do not test their composite samples oftener than every 15 days. Troy [46] recommends that two drops of formaldehyde be added to each composite sample bottle before anything else is added to it. This is recommended as being useful

[46] Troy, H. C., Cornell University, from unpublished data.

in preventing the growth of mold in the sample, and formaldehyde is of itself a preservative for milk. Mercuric chloride is a violent poison and composite samples should be colored to prevent anyone mistaking them for milk which is fit to drink. The preservative tablets sold by dairy supply houses always impart some distinct color such as green, pink or dark brown, to the composite sample.

Cream contains such a large proportion of fat to other milk solids that it is not practicable to keep composite samples of cream. Cream gathering plants have the laborious task of testing each batch of cream when it is received.

The following precautions should be observed in keeping composite samples:

1. Care should be taken to see that the preservative is dissolved.

2. The sample should be shaken whenever it is taken from the shelf. This will mix the preservative with the entire sample and will wash down any cream adhering to the side of the bottle.

3. Each sample bottle should be numbered or have some definite way of distinguishing it.

4. The bottles should be kept in a cool place, as the sample will keep better than if it is warm.

5. The samples should be kept in a dark place, as light tends to weaken the preservative.

6. The bottle containing the sample should have a tight stopper so that the samples will neither lose nor take on moisture.

7. The cupboard containing the sample bottles should be kept locked so that they cannot be tampered with.

In spite of all precautions, composite samples sometimes become rather hard and dry on the surface of the liquid and when mixed for testing a small brush is necessary to obtain an even mixture. It may also be necessary to warm the sample but it should not be heated above 90° F. as the sample is liable to oil off. When this happens it is impossible to mix the fat evenly through the milk again.

THE FRAUDULENT USE OF PRESERVATIVES IN MILK

A change in the percentage composition of the total solids of milk or cream changes the weight of a given volume of either one of them. In milk this change in weight is slight and the weight of a quart

of milk is considered as 2.15 pounds. The percentage composition of the total solids of milk is very variable and the most variable constituent of cream is the fat; this would naturally cause a big variation in the weight of a given volume of different samples of cream. For this reason in converting quarts of cream to pounds or converting pounds of cream to quarts, it is necessary to know the percentage of fat of the product and use a weight per given volume of cream which corresponds to that particular percentage of fat.

The following table [47] shows the specific gravity and weight per gallon of water and skimmilk and also of milk and cream of various percentages of fat.

Table 32.—Weights and Specific Gravity of Milk and Cream Containing Different Percentages of Fat.

	Percentage of Fat	Specific Gravity	Weight per Gallon (Pounds)
Water	....	1.000	8.32162
Skim	0.025	1.037	8.6295
Milk	3.	1.034	8.6045
Milk	3.5	1.033	8.5962
Milk	4.	1.032	8.5879
Milk	5.	1.031	8.5796
Milk	6.	1.030	8.5713
Mixed milk and cream	10.	1.025	8.5297
Mixed milk and cream	13.	1.018	8.4714
Cream	18.	1.015	8.4464
Cream	20.	1.013	8.4298
Cream	22.	1.011	8.4132
Cream	25.	1.008	8.3882
Cream	28.	1.006	8.3715
Cream	30.	1.004	8.3549
Cream	32.	1.002	8.3383
Cream	35.	.999	8.3133
Cream	38.	.997	8.2967
Cream	40.	.995	8.2800

The practice of adding preservatives to milk is sometimes followed by unscrupulous dairymen. These preservatives are used to keep the milk longer than it otherwise would under normal conditions, and in nearly all states and cities this practice is forbidden by law. The main objections to allowing the addition of a preservative to milk, whether it is harmful or not are as follows:

[47] Milk plant letter, number 119, Dairy Division, United States Department of Agriculture.

1. It tends to promote carelessness on the part of both the producer and those handling the milk. If it is known that the results of dirty methods will be covered up, it creates a tendency to be less careful in the care of milk.

2. In some cases a preservative might be used which in itself would not be harmful. It has, however, been the experience of food inspectors that allowing the use of a harmless preservative tends to increase the use of those which are harmful, and this greatly increases the difficulty of inspection.

3. The use of preservatives makes it possible to place on the market milk which is unfit for human consumption, and this is especially true in regard to infant feeding. Milk might be old and contain large numbers of bacteria and yet if preservatives were added to it, further bacterial development would be checked for a time and the true sanitary condition of the milk might not be detected by the consumer.

4. The use of preservatives tends to destroy the confidence of the consuming public in the food value of milk. This means that there is less of the product sold.

5. The preservative itself may be poisonous.

The fact should be emphasized that comparatively few attempts are made to add preservatives to milk. Most dairymen realize the harmful consequences which might result from such a practice, and they also realize that in the long run the unlawful use of preservatives would result in a financial loss to the industry as a whole. Furthermore, the milk supplies of most of our cities are under supervision of a competent system of inspection, and any extended practice of adding preservatives to milk will sooner or later be discovered.

It would be impossible to give all of the preservatives which might be added to milk. In the following pages are given a few of the more common ones, together with the method for their detection. These are given not only for the intrinsic knowledge in regard to them, but also to show the general type of preservatives which might be used.

FORMALDEHYDE OR FORMALIN

The word formalin is often used in the place of the word formaldehyde. Formalin is a trade name used to indicate a 40 per cent

solution of formaldehyde. This is one of the most common substances used to preserve milk fraudulently as it is cheap, easy to obtain and is very effective. One part of formaldehyde to 20,000 or 25,000 parts of milk will keep milk sweet from two to four days longer than it otherwise would keep. Formaldehyde is poisonous and is accumulative in the system. In addition it forms a tough compound with the casein of milk and renders it indigestible. The test for formaldehyde is very simple and delicate, one part of formaldehyde to 250,000 parts of milk being easily detectable. This is possible, however, only when the milk is comparatively fresh. As the sample becomes older the formaldehyde forms more stable compounds with the milk and after the milk is 36 to 48 hours old, the test becomes unreliable. The test for formaldehyde may be performed in connection with the Babcock test. After measuring the sample into the test bottle, three or four drops of ferric chloride are added to it. The regular amount of sulphuric acid is then added, care being taken to let it run down the sides of the bottle in such a way that it will not mix with the mass of casein. At the line where the acid and casein meet, there will be a deep lavender color if formaldehyde is present. The acid and casein may then be slowly mixed and the lavender color will become more evident. If no formaldehyde is present, the line where the sulphuric acid and casein meet will be brown or black in color.

PEROXIDES

The double oxides depend for their preserving power on milk upon the fact that certain enzymes in milk attack the oxide and liberate oxygen, and the free oxygen prevents bacterial growth. Peroxidase is the name of the enzyme which most investigators give as the one causing the reaction. Russell and Babcock have described another one which they call galactase and which is similar to trypsin.

The most common peroxide which might be used as a preservative of milk is hydrogen peroxide. Calcium, magnesium, or strontium peroxide might also be used. The test for these double oxides consists in adding to 10 c.c. of milk, in a clean test tube, a small amount of paraphenylendiamine-hydrochloride, such as might be held on the point of a knife blade. This powder is well shaken with the milk and if peroxides are present, a deep blue color will result. If no

peroxides are present, there will be either no change in color or else a slightly dark color. When mixing the paraphenylendiamine-hydrochloride with the milk, care should be taken not to get it on the hands as it discolors the skin. It should be noted that this test is unreliable if milk has been heated high enough to kill the enzymes in milk. The exact temperature at which this occurs is much disputed and unquestionably the length of time heat is applied has considerable influence on the exact thermal death point of enzymes. The test has been found uncertain if milk is heated to 165° F. (73.8° C.).

BOILED MILK TEST

This test should be studied in connection with the tests for peroxides as it may be considered the reversal of the test for peroxides in milk. It depends for its action on the fact that living enzymes have the power of liberating oyxgen from a double oxide. There are several methods used to detect boiled milk but two of them are in common use and the most satisfactory method is as follows: To 10 c.c. of milk in a clean test tube add such an amount of paraphenylendiamine-hydrochloride as can be held on the point of a knife blade and then add approximately the same amount of calcium peroxide or four or five drops of hydrogen peroxide. If the sample of milk has not been heated high enough to destroy the enzyme peroxidase, a blue color will result. If the sample of milk has been heated high enough to destroy the enzymes, either there will be no change in color or a slight darkening of the contents of the tube.

The second method of testing for boiled milk is as follows: To 10 c.c. of milk in a clean test tube add 3 c.c. of a solution of starch, 1 c.c. of potassium iodide solution, and 1 c.c. of hydrogen peroxide or a small amount of calcium peroxide. Shake the contents of the tube thoroughly and if the milk has not been heated, a blue color will result. If the sample of milk has been heated high enough to destroy the enzymes, a pale yellow color will result. This test requires from three to five minutes to act and it will act with greater rapidity if the sample is warmed to 90° F.-100° F. (32.2° C.-37.7° C.).

TEST FOR GELATIN IN MILK

Gelatin is sometimes fraudulently used in cream to give it a heavy body. The test is as follows: To 10 c.c. of cream in a test tube add 10 c.c. of a solution of acid mercuric nitrate. Shake the contents of the tube thoroughly three or four times at three to five minute intervals. Filter the solution and to some of the filtrate add an equal amount of a saturated solution of picric acid. If gelatin is present, a cloudy precipitate will result,—and if the gelatin is present in large quantities, the precipitate will be yellow in color. If no gelatin is present, the solution will remain clear.

The acid mercuric nitrate is prepared by dissolving a given weight of mercury in twice its weight of nitric acid, and then diluting the solution with an equal volume of water.

THE SEDIMENT TEST

There is necessarily no direct connection between the amount of visible dirt in milk and the numbers of bacteria present. However, a large amount of dirt is quite apt to mean a high bacteria count and this is more liable to be true if the milk is comparatively old. Fresh milk may contain a large amount of visible dirt and not be as high in bacteria count as an old sample of milk which has a small amount of visible dirt simply because the bacteria in the fresh milk have not yet had time to multiply.

Visible dirt is, moreover, an indication of the care exercised in milk production and while the dirt in milk at any one particular time may not carry large numbers of bacteria, it is not the care exercised by the producer which prevents this from being the case. One of the chief values of the sediment test is the fact that it is readily understood by the milk producer. Microörganisms cannot be seen by the naked eye and despite the effort made to promote education in regard to them, bacteria and the results of their action remain more or less of a mystery. Visible dirt, such as straw, chaff, hairs, and even small particles of manure, can be easily recognized, and few milk producers, even careless ones, like to have it generally known that milk produced by them contains such excessive amounts of foreign materials.

There are various types of sediment testers on the market, but

nearly all of them make use of a cotton disc, through which milk is forced by air pressure, the pressure being supplied by an ordinary rubber syringe bulb. The amount of milk taken for the test is usually a quart, although in some cases a pint may be used. Since much of the sediment found in milk is heavier than the milk itself, great care should be taken to stir the milk thoroughly before the amount used for the sediment test is withdrawn. This will force the sediment into suspension and it will be represented on the disc. When the discs are dried, the dirt will stick to them with great tenacity and the discs may be pasted on cardboard and kept intact for future reference for months.

METHYLENE BLUE REDUCTION TEST

The action of this test depends on the fact that when methylene blue is added to milk and the samples kept at 37° C. (98.6° F.) the color is reduced by the action of bacteria. This test is very easy to perform and from that standpoint is desirable for use in milk plants as a cheap and fairly rapid means of grading milk. There has been much dispute in regard to the efficiency of the test and the significance of the reduction which takes place.

One thing on which all investigators are agreed is that a weak solution of the methylene blue is essential. Methylene blue has an antiseptic action upon milk and a strong solution will undoubtedly retard bacterial growth.

Hastings, Davenport, and Wright [48] recommend using 1 c.c. of the methylene blue solution in 10 c.c. of milk. The methylene blue, when so used, should have such a concentration that the dilution in the milk will be approximately 1 to 200,000. Troy [49] working in a large number of milk plants, under practical conditions, compared the methylene blue reduction test with the direct microscopic method. He found that so far as grading milk was concerned, there was in 90 per cent of the cases a distinct correlation between the methylene blue reduction test and the direct microscopic method.

[48] Hastings, E. G., Davenport, A., Wright, W. H., The Influence of Certain Factors on the Methylene Blue Reduction Test. Journal of Dairy Science, Vol. 5, page 438.
[49] Troy, H. C., Cornell University, unpublished data.

COLORING MATTER IN MILK

In the popular mind, a yellow color in milk and cream is associated with a high fat content and for this reason these products are sometimes fraudulently colored. The two kinds of colors most used are annatto, and some of the coal tar dyes.

The test for annatto is made by shaking equal volumes of milk and ether in a test tube. This is repeated several times. The tube is then allowed to stand and a solution of ether and fat will rise to the surface of the solution. If annatto is present, the ether will turn a yellow color.

The test for the coal tar dyes is made by dissolving 10 c.c. of milk in 10 c.c. of strong hydrochloric acid. If any of the coal tar dyes are present, the solution will turn pink.

TEST FOR SODIUM CARBONATE IN MILK

Sodium carbonate (Na_2Co_3) and sodium bicarbonate ($NaHCo_3$) are sometimes added to milk for the purpose of neutralizing acidity. The test for carbonates is performed as follows: To 10 c.c. of milk add an equal volume of alcohol. Shake thoroughly and add about 10 drops of a 1 per cent solution of rosolic acid. If carbonates are present, a rose red color will appear, but if no carbonates are present, the solution will turn a brownish yellow.

BORAX AND BORIC ACID

Borax and boric acid have oxidizing powers and for this reason they are sometimes added to milk as a preservative. Borax is (sodium borate) also slightly alkaline and tends to neutralize acid.

The test for boric acid and borax is as follows: To about 25 grams of milk add lime water until the milk is alkaline. The purpose of adding lime water is to make less volatile any boric acid which might be present. Burn the milk to ash and moisten the ash with a few drops of weak hydrochloric acid. Then add a small amount of water and with a glass rod stir the ash and water. In this mixture moisten some strips of tumeric paper and if borates are present, the tumeric paper will turn a cherry red color. To further confirm the test add a drop of some weak alkali; e.g., sodium hydroxide,

to the tumeric paper. If borates are present, the cherry red will turn an olive green color. When an alkali is added to ordinary tumeric paper, it will turn a deep red.

TEST FOR NITRATES

The test for nitrates is used in milk-control work as a confirmatory for adulteration of milk by watering. Since nitrates are not present in milk and are present in water, a positive test for nitrates in milk is a strong indication that the milk has been watered.

A solution is made by mixing 1 c.c. of diphenylamine with 100 c.c. of sulphuric acid. Place in a test tube about 5 c.c. of milk and add the solution slowly to it, allowing the solution to run down the side of the tube in such a way that the milk and acid solution will not mix. If nitrates are present, a blue color will appear at the point where the acid and milk come in contact with one another. The color must be quickly noted as the action of the acid on the milk will soon cause a dark brown or black color. Different strengths of the diphenylamine and sulphuric acid are used. Smaller amounts of the former tend to make the color reaction slower.

BOILING TEST

The boiling test consists in boiling milk and noting whether or not the casein coagulates. It is especially useful in determining whether milk will stand the process of pasteurization and also that of condensing. Milk is said to coagulate when heated to the boiling point, if it contains .26 per cent acid. It is true that milk which would coagulate on boiling might not coagulate at pasteurization temperatures. If, however, it is of such poor sanitary quality that boiling temperatures will precipitate the casein, it should not be used for market milk purposes.

THE CURD TEST

The curd test is most useful in determining which one of several patrons is bringing heavily contaminated milk to a milk plant, and thus contaminating the entire supply. The milk of the patron, or patrons, if there be more than one causing the trouble, can then be kept from the general supply. The test depends on observing the

appearance of the sample when kept for from six to twelve hours at a temperature favorable for bacterial growth. Naturally, samples which are most heavily contaminated will show the effects of bacterial action sooner and to a more marked degree than samples having a low bacterial content.

There are two general methods of performing the curd test and one of them is as follows:

Sterilize as many test tubes as may be necessary, plugging them with cotton plugs before sterilization. Place into each sterile tube 10 c.c. of milk, using a sterile pipette for each sample. If enough pipettes are not available, the same one may be used for different samples providing it is cleansed after each successive use. This may be accomplished fairly well by rinsing the pipette in cold water and then rinsing at least three times in boiling water. Under these circumstances the chances of carrying contamination from one sample to another is slight. It must be admitted, however, that there is this possibility of contamination and more dependable results will be obtained if a sterile pipette is used for each sample. To each tube of milk add four or five drops of a weak solution of sterile litmus and mix the litmus thoroughly with the milk. Strong litmus solution should not be used as it has an antiseptic effect on milk. The tubes should be numbered or marked in such a way that they can easily be identified. They should then be placed in a water bath at a temperature of 37° C. (98.6° F.) and held at that temperature for six to twelve hours. During that time the contents of the tubes should be observed for rapidity of acid formation, curdling, and the formation of gas pockets in the curd. The acid formation is, of course, indicated by the blue litmus turning red. The tubes should also be examined from time to time to see if any bad odors are formed, although bad odors would not be as easily distinguishable as would be the case if larger amounts of milk were used.

The second curd test is usually referred to as the Wisconsin Curd Test and is performed as follows: Sterilize as many pint or half-pint jars as may be necessary. Fill the jars with the milk to be examined, taking care not to carry the contamination from one lot of milk to another. If a dipper is used to fill the jars, it should be rinsed in luke warm water after each use, and then held in boiling water for at least one minute. In most cases this will prevent trans-

ferring the contamination from one sample to another. The sample jars are then set in a water bath at a temperature of about 95° F. (35° C.) and when the milk has reached this temperature about ten to twelve drops of rennet are added and thoroughly mixed with the milk by shaking. A firm coagulum will form in about twenty to twenty-five minutes and this should then be cut with a sterile knife and the whey poured off. This process is repeated until all the whey possible has been removed from the curd. Care should be taken to flame the knife after cutting the curd in each jar, as otherwise contamination might be carried from one jar to another. When all the whey possible has been drained from the curd, it is allowed to mat in the bottom of the sample jars. The jars should then be held in a water bath at a temperature of approximately 95° F. (35° C.) for from six to twelve hours, and during that period they should be examined from time to time for bad odors and flavors and the formation of gas. The presence of gas may be detected by cutting the matted curd with a sharp sterile knife and noting if any holes have appeared in the curd.

It sometimes happens that the trouble may be traced to a single cow in a herd from which the supply of milk is obtained.

While this test is more or less crude, it is easily performed and is inexpensive and very frequently will point out the source of contamination. Too much stress, however, cannot be placed upon the necessity of preventing contamination from outside sources, such as unsterile jars, unsterile knives, and dusty atmosphere.

THE ALCOHOL TEST

The alcohol test consists in mixing equal parts of milk and 68 per cent to 70 per cent alcohol. The amounts usually taken are 2 c.c. of each and these are shaken in a test tube. If the milk is abnormal, flakes of casein will be precipitated although there seems to be no regularity in regard to the amount of coagulum or the size of the particles precipitated.

Ayers and Johnson [50] in studying the alcohol test are of the opinion that this test must be studied from two standpoints; namely, that of the individual cow and that of the large supply of mixed

[50] Ayres, S. Henry, and Johnson, Wm. T., The Alcohol Test in Relation to Milk, U. S. Dept. of Agriculture, Bull. No. 202.

milk. In the former case a positive test is apt to indicate a pathological condition of the udder and in the latter case its significance is more that of bacterial action. However, the authors did not find any definite relation between a positive alcohol test of milk and the numbers of bacteria in the sample. However, this may be due to the fact that, although milk may have a high bacteria content, the organisms present have not produced any chemical changes in it.

All investigators seem to agree that a positive alcohol test is indicative of changes in milk due either to pathological conditions or the presence of products produced by bacteria. However, the reasons why the alcohol test will sometimes give negative and sometimes positive reactions are not definitely known, and until these facts have been worked out more definitely, the alcohol test will have little value as a means of determining the sanitary quality of market milk.

THE ALIZAROL TEST

In connection with the alcohol test should be mentioned the alizarol test which was suggested by Morres.[51] The alizarol test is an acidity test and is based on the theory that milk with high acidity has been subjected to improper methods of production or handling, such as improper cooling or handling in improperly cleaned utensils. Alizarin is an indicator and in this test it is added to 68 per cent alcohol at the rate of 0.4 grams of alizarin powder to 1 liter of alcohol, and 2 c.c. of this solution are mixed with 2 c.c. of milk the same as in the regular alcohol test. Morres claims that different percentages of acid in the milk will give definite color reactions with alizarin, e.g., fresh milk with .16 per cent acid will give a lilac red color, milk with .25 per cent acidity a brown color, milk with .36 per cent acidity a yellow color. In connection with this test Morres also takes into account the amount and character of the coagulation of the casein. This test has never been applied to any extent in this country to determine the sanitary quality of market milk.

[51] Morres, Wilhelm. Jur. Alkoholprobe der Milch. In Molkeri-Zeitung Vol. 23, No. 47.

Chapter VI

THE BACTERIOLOGICAL EXAMINATION OF MARKET MILK

In the examination of milk for bacteria two methods are employed, one the plate method and the other the direct microscopic method. In the use of either method it is necessary to have the sample a representative one and great care should be exercised to have the containers sterile and to prevent contamination of the sample after it is taken.

Plate method of counting bacteria

Bacteria in milk tend to come together in groups or clumps, and unless these are broken up, the amount drawn for examination will not be a representative one. In order to promote uniformity of results the rule has been adopted of shaking the sample twenty-five times before removing any for examination. The actual amount drawn for examination is 1 c.c. and on account of the number of bacteria present and the opaqueness of the milk, this amount of 1 c.c. is diluted in sterile water.

The amount of dilution will depend on the number of bacteria in the milk and therefore in order to determine the proper dilution to make it is necessary to know the history of the sample to be examined. Even with this knowledge the proper dilution is uncertain and it is customary to make three different dilutions which vary quite widely. If nothing whatever is known concerning the history of the sample, even more than three dilutions are sometimes made. The first dilution is usually one c.c. of milk in 99 c.c. of sterile water, thus making a dilution of 1 to 100. This dilution is an easy factor with which to work in making further dilutions. One c.c. of the diluted sample is then placed in a sterile glass dish called a Petri plate, two plates being made from each dilution, so that one will be a check on the other. A sterile 1 c.c. pipette, usually gradu-

ated in tenths of cubic centimeters, is used to transfer the diluted sample to the Petri plate. Some media on which bacteria will grow is then added to the Petri plate. Several kinds of media may be used, the two most common being nutrient gelatine and nutrient agar. Agar is used more than gelatine in examining milk because it does

FIG. 4. Materials Used in Determining the Number of Bacteria in Milk by the Plate Method.

not liquefy at ordinary temperatures as does gelatine. Whatever media is used, must of course be added to the Petri plate in a liquid condition, and care must be taken to distribute the medium evenly over the surface of the plate so that the colonies of bacteria when they grow will be evenly distributed over the entire area and can therefore be more evenly and more accurately counted. If agar is used it must, as stated above, be melted, and since this requires a

temperature near the boiling point the medium must be cooled to a temperature sufficiently low when poured into the Petri plates to prevent its killing the bacteria in the material being examined. The temperature at which agar is usually held at time of pouring is 43° C. (109.4° F.). If the temperature falls much below this, the agar will solidify.

The plates should be kept level while the medium in them is hardening, so that the thickness of the medium will be the same over the entire area of the plate. After the medium has solidified the plates are placed in an incubator and allowed to remain there for forty-eight hours to give the bacteria time to grow. The plates should be put into the incubator bottom side up, so that the water of condensation, which nearly always forms in large drops on the cover of the Petri plates, will remain there. If this were not done, the condensed water might run over the surface of the medium and carry contamination from one part of the plate to another.

The temperature at which the plates are incubated will depend on the medium used. Agar plates are incubated at 37° C. (98.6° F.), while gelatine plates are incubated at 20° C. (58° F.). Gelatine melts at about 22° C. (71.6° F.) and for this reason it is difficult to work with it in warm weather, but it has the advantage of being liquefied by certain bacteria. The bacteria which liquefy gelatine are regarded as putrefactive types and from this standpoint gelatine is useful in helping to differentiate the bacteria in milk. Litmus is also frequently added to gelatine which is slightly alkaline in reaction and the mixture is blue in color. If a colony produces acid, the medium surrounding the colony will turn red. This is another method of helping to identify species of bacteria.

After incubating forty-eight hours the colonies in the plates are counted and the numbers of bacteria in the plates are computed. (For illustrative example see Chapter 21, Problem No. 26.)

Each colony contains millions of bacteria but in counting each colony as though it were a single bacterium it is assumed that the colony was started by a single organism, the same as a stalk of wheat which contains many kernels was started by a single wheat kernel. Each colony therefore represents a single organism which was in the milk and by multiplying the number of colonies in the plate by the rate of dilution, the bacteria per cubic centimeter in

the milk are obtained. It is desirable to dilute the milk to such an extent that there will be not over seventy-five colonies in a plate. However, it very frequently happens that the dilution is not high enough and so many colonies develop that it is impossible to count the entire plate. In such an instance it is customary to count ten square centimeters and average them, finding the average number of organisms in one square centimeter. This number is then multiplied by the number of square centimeters in the Petri plate which is usually sixty-four.

In selecting these ten squares, each containing one square centimeter, great care should be exercised in selecting those which are, so far as possible, representative of the entire plate. It would cause great inaccuracy of results to select those which contained only a few colonies if a larger percentage of the area of the plate contained a large number of colonies. (For illustrative example see Chapter 21, Problem No. 27.)

Theoretically the duplicate plates of the same dilution should contain the same number of colonies but this rarely happens. There should, however, not be a wide variation in the number of colonies in plates of the same dilution and it is customary to average the duplicate plates.

The average count of the duplicate plates containing the different dilutions is then computed to obtain the number of bacteria in the material being examined.

If any plate gives evidence of outside contamination or is abnormal in any way, it should of course be discarded.

In counting the colonies in a Petri plate it is necessary to use a square piece of glass called a counting plate. This counting plate is ruled into areas of one square centimeter and some of the square centimeter areas are again subdivided into square millimeters. These subdivisions make it easier for the eye to distinguish the divisions on the plate and makes it possible to do more accurate counting. In counting bacteria the Petri plate should be placed on the counting plate and kept in one position during the entire time the plate is being counted. If this is not done the same colony might be counted more than once.

One of the best methods of holding the counting plate is to place it between the ring and middle finger of the left hand and place

the Petri plate on top of it. The Petri plate may then be held in position by the index finger and thumb of the left hand. A dark background makes it easier to see the colonies on the plate and for this reason a piece of black paper is sometimes pasted on the back of the counting plate.

Many of the colonies are so small that it is impossible to distinguish them with the naked eye and for this reason a hand magni-

FIG. 5. Proper Method of Holding Petri Plate in Counting Bacteria.

fying glass should always be used in counting plates. If the counting plate is held as described above, the magnifying glass may be held in the right hand, and this makes it easy to keep the colonies in proper focus.

DIRECT MICROSCOPIC METHOD OF MILK EXAMINATION

The second method of examining market milk for bacteria is by placing some of the milk under the microscope on a glass slide, and

counting the bacteria in it. This is called the direct microscopic or Breed method. Special slides properly ruled are made for this purpose but an ordinary glass slide will answer very well. When an ordinary glass slide is used it is placed over some object which has square centimeter divisions on it, as, for instance, a counting plate, and square centimeter areas are marked off with a red glass marking pencil. These square centimeter areas may also be drawn with a ruler if no guide is available. One one-hundredth of a cubic centimeter of the milk to be examined is measured by means of a special pipette and spread, with a platinum loop or needle, over the square centimeter area on the glass slide. The layer of milk should be spread as evenly as possible.

The sample is then allowed to dry thoroughly in air. The drying process may be hastened by holding the slide between the thumb and finger over a gas flame but great care must be exercised not to dry the slides too rapidly or else the film of milk will crack. After the film has thoroughly dried it is soaked in a dish of xylol for three to five minutes in order to dissolve the fat. The slide is then removed, the xylol shaken off and allowed to dry in air and not over a gas flame as the xylol is inflammable. The slide is next immersed in 95 per cent alcohol for three to five minutes in order to fix the film of milk on the slide. It is then immersed in a solution of aqueous or alcoholic methylene blue for two to three minutes and then removed and all of the stain possible shaken off and the slide decolorized in 95 per cent alcohol until it is of a pale blue color. If an aqueous solution of methylene blue is used, it must be watched carefully to see that it does not become contaminated with bacteria, and so introduce a grave source of error. After staining and decolorizing in alcohol the preparation is ready to count and this is best done under a high power microscope with an oil immersion objective. If the slide has been properly prepared, the bacteria will be seen deeply stained with a pale blue background of milk serum.

In enumerating the bacteria seen under the microscope it is customary to count the number of so-called "sources" per field. A source is defined as a single organism or chain or clump of organisms which would produce a single colony if the material had been examined for bacteria by the plate method.

In examining milk for bacteria by the direct microscopic method,

if there are less than two sources per ten fields, count 100 fields; if there are two to ten sources per field, count 60 fields. If there is over one source per field, count 30 fields or less.

It is possible to convert the number of sources found in the field of the microscope into terms of numbers of bacteria per c.c. and this is done by multiplying the number of sources found by the so-

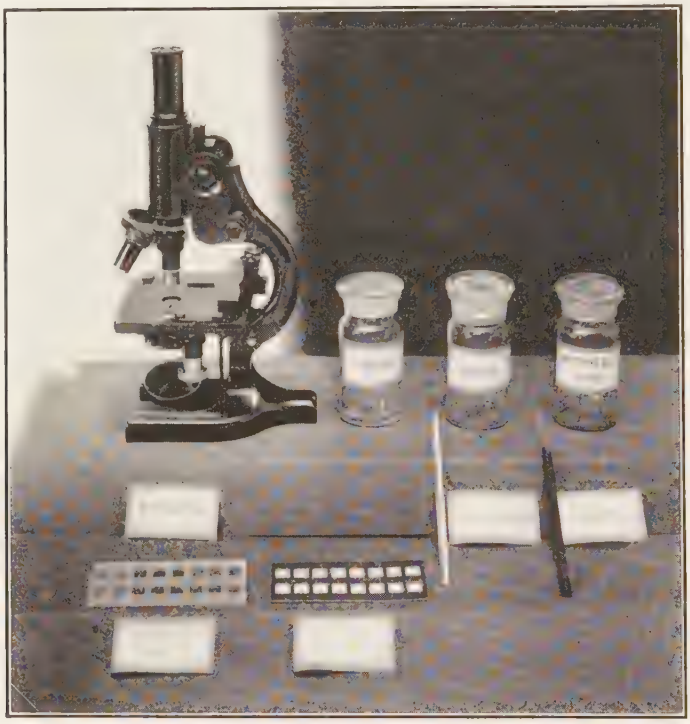

Fig. 6. Equipment Used in Making a Count of Bacteria in Milk by the Direct Microscopic Method.

called "factor" of the microscope. The factor of the microscope is the number of times the amount of milk seen under the field of the microscope would have to be increased to make it the equivalent of 1 c.c.

The factor of a microscope is usually several hundred thousand, depending on the length of the draw tube and the size of the ocular and objective of the microscope.

In order to obtain the factor it is first necessary to locate the draw tube of the microscope at a fixed point and then obtain the diameter of the field by means of a micrometer. The micrometer is a glass slide with accurate rulings, usually .01 mm. apart, and by counting the number of .01 mm. spaces seen under the field of the microscope, the diameter of the field can be obtained.

The formula πr^2 will give the area of the field in terms of a fraction of a sq. mm. The number of fields required to equal 1 sq. mm. is next found by dividing 1 sq. mm. by the area of the field of the microscope. This figure is then reduced to terms of sq. cm. by multiplying it by 100, the number of sq. mm. in 1 sq. cm. This last product is then multiplied by 100 because we desire our answer in terms of c.c. and only .01 c.c. of milk were taken for examination.

Problem numbers 28 and 29, Chapter 21, show respectively the method of obtaining the factor of a microscope and of computing the number of bacteria per c.c. in milk when the microscopic count is given.

In obtaining the factor of the microscope it is customary so to adjust the draw tube that the factor will be an even number or so close to it that the factor used is called an even number.[52] This is done to make the factor easier to use and with the ordinary oil immersion microscope the factors of 500,000 and 300,000 are very commonly used. It is better to use the latter factor if possible because the smaller the factor used the less any error which may be made is increased.

[52] Breed, Robert S., and Brew, James D., Technical Bul. No. 49, N. Y. State Exp. Sta.

Chapter VII

THE FOOD VALUE OF MILK, AND THE USE OF MILK AS A FOOD

A food may be defined as any substance which when taken into the body will form tissue and furnish heat for the body. The food is taken into the stomach and undergoes what we call digestion, being converted by different digestive juices into material which can be taken up by the system and converted into tissue. Just how this last process is accomplished is not definitely known. In the process of digestion, heat, or as it is commonly called, energy, is liberated. Energy is usually expressed in terms of calories, and a calorie is defined as the amount of heat required to raise one gram of water one degree centigrade.

Foods are divided into groups or classes which are called digestible nutrients and these groups are named as follows: (1) Fats, (2) carbohydrates, (3) proteins, (4) and mineral matter. The latter is sometimes called ash because the mineral matter is supposed to be undestroyed by burning the material. The ash of any material may not, however, exactly represent the mineral content of the original material because the mineral content may be changed by the action of heat.

Water is placed in a group by itself and is not called a food, yet without it growth and therefore life itself would be impossible. Water also plays a very important part in converting other food substances into a solution (e.g., sugar), emulsion (as in case of fats) or a colloidal condition (e.g., casein). This increases the ease of digestibility of these substances.

Each of the different groups mentioned has its special function in supplying the needs of the body. The fats and the carbohydrates contain carbon hydrogen and oxygen and supply heat or energy, the fats supplying 2¼ times as much energy as the carbohydrates.

The fats contain a much higher percentage of carbon than do the carbohydrates. Strictly speaking, the carbohydrates contain hydrogen and oxygen in the correct proportion to form water although in discussions on this group of nutrients this fact is not always adhered to. The proteins in addition to carbon, hydrogen and oxygen contain nitrogen and a comparatively small amount of sulphur. The nitrogen is necessary in promoting growth and in the production of products of secretion, such as milk. It is combined with the other elements in a great variety of forms, and this renders the chemical structure of a protein very complex. As a matter of fact, it is impossible to make a definite and exact chemical analysis of a protein. From a chemical standpoint there is no difference between vegetable and animal protein, yet physiological results show there is a difference.

The mineral content of food consists mainly of salts of calcium iron, potassium, magnesium, sulphur and phosphorous. There are other minerals present in small amounts and all of these are in a great variety of chemical combinations, some of them in very complex organic compounds. The mineral matter is mainly found in the bones and teeth of animals, although it is a regular constituent of both plant and animal tissues. In analytical work the mineral matter is usually referred to as ash because it is obtained by burning the substance at as low a temperature as possible and still have complete combustion. As has already been pointed out, ash may not represent in all cases the true mineral content of a substance, as it may have undergone changes due to heat.

The body can to a certain extent substitute one digestible nutrient for another. This function is, however, limited and is thought to be more or less of a tax on the system.

In order to be a food a substance should fulfil the following requirements:

1. It should contain all of the digestible nutrients. Not all substances do contain all of the digestible nutrients but they are used constantly in the daily diet in combination with other substances which supply the nutrients in which they are lacking.

2. A food should contain the digestible nutrients in the proper proportion: e.g., there should not be an excessive amount of protein present in proportion to the carbohydrates. In considering

this characteristic of a perfect food, it is possible to make definite statements only within rather wide limits because the purpose for which a food is intended is one of the most important factors in nutrition. An ideal food for a beef animal would obviously not be an ideal food for a milk-producing animal, and the demands of different foods for different purposes make it necessary to balance a ration, i.e., to supply the proper proportion of digestible nutrients for the purpose intended.

3. A food should be digestible. The term digestible is used rather indefinitely. Strictly speaking, anything is digestible when, on being taken into the stomach, it can be converted by the different digestive juices into body tissue. In the case of any certain substance, the more completely this process takes place without any residue being left, the higher the substance is regarded as a food. Even here there is difficulty in a strict application of the definition of digestibility, since it has been found that a certain amount of residue (crude fiber) is necessary to stimulate the digestive tract and keep it in its highest state of efficiency.

Another sense in which the term digestibility is used is whether or not certain foods agree with any one. Certain people cannot retain in their stomach certain foods, although the substances are readily capable of being converted by the digestive juices into bodily tissue. On the other hand, these same foods are eaten and relished by others. It is these idiosyncrasies of different people which makes the work of the dietician so difficult.

4. A food must be free from all substances harmful to the system. This refers both to chemical preservatives and adulterants and to products which are the results of the action of microörganisms.

5. A food must not be prohibitive in price. While this qualification has nothing to do with foods from a physiological standpoint, it is none the less important. No matter what qualifications a certain food may possess, if it is too costly to be within the reach of the buying public, it will not be purchased and its value as a food is lost. It is a well-known fact among people connected with the dairy industry that the consuming public will object more to a raise in price of dairy products, especially fluid milk, than they will to a raise in price of other staple food commodities, such as meat and flour.

From a physiological standpoint, milk is one of our best foods. It is also one of the cheapest foods from the economic standpoint, although it is not usually so regarded, and cutting down on the fluid milk supply is one of the first things done in an effort to reduce the household expenses. Milk is too often regarded as a beverage rather than the valuable food which it is, and it has been definitely proven that the use of milk in the diet will result in a less consumption of other foods.

Table 33.—Common Foods in Respect to Their Refuse, Water Content, and Digestible Nutrients.

Food Materials	Refuse	Water	Nutrients				
			Protein	Fat	Carbohydrates	Mineral Matter	Fuel Value
Milk (1 pint)	Pound	Pound	Pound	Pound	Pound	Pound	Calories
Whole milk	..	0.87	0.03	0.04	0.05	0.01	325
Skimmilk (0.3% fat)	..	.90	.04	..	.05	.01	170
Buttermilk	..	.91	.03	.01	.05	.01	165
Other food materials (1 pound each)							
Cheese	..	.34	.26	.34	.02	.04	1,965
Butter	..	.11	.01	.85	..	.03	3,605
Beef:							
Round	0.08	.61	.18	.12	..	.01	870
Shoulder	..	.69	.19	.11	..	.01	835
Sirloin	.13	.53	.16	.17	..	.01	1,040
Fore quarter	.19	.50	.14	.16	..	.01	950
Hind quarter	.16	.51	.15	.17	..	.01	1,000
Mutton, side	.19	.43	.13	.24	..	.01	1,275
Pork:							
Loin	.16	.44	.14	.25	..	.01	1,340
Ham	.14	.35	.13	.34	..	.04	1,655
Salt, fat	..	.07	.02	.87	..	.04	3,715
Chicken	.35	.48	.15	.01	..	.01	325
Codfish:							
Fresh	.30	.58	.11	..	..	.01	205
Salt	.25	.40	.16	..	..	.19	315
Mackerel, salt	.23	.38	.17	.17	..	.10	1,050
Oysters, solids	..	.88	.06	.02	.03	.01	235
Wheat flour	..	.12	.11	.01	.75	.01	1,645
Corn meal	..	.13	.09	.02	.75	.01	1,655
Oatmeal	..	.07	.16	.07	.68	.02	1,860
Wheat bread	..	.35	.10	.01	.53	.01	1,205
Crackers	..	.08	.11	.10	.69	.02	1,895
Dried beans	..	.13	.22	.02	.59	.04	1,590
Beets	.20	.70	.01	..	.08	.01	170
Potatoes	.15	.67	.02	..	.15	.01	325
Turnips	.30	.62	.01	..	.06	.01	135
Apples	.25	.62	.01	..	.12	..	255

Why milk ranks high as a food.—1. It contains all of the digestible nutrients. By referring to Table 33 it will be seen that some of our most common animal foods are lacking in one or more of the digestible nutrients.

2. There is no waste or refuse to milk and this is also true of nearly all dairy products.

3. Milk ranks high in digestibility as is shown in Table 34, and more of milk is digested when eaten in combination with other foods than when it is eaten alone.[53]

Table 34.—Digestibility of Milk as Compared with Animal Foods.

	Fat	Protein	Carbohydrates
Animal foods	95%	97%	98%
Milk	99%	98%	99%
Ordinary diet	95%	92%	97%

4. Some of its contents are in the form of an emulsion[54] (fat), a colloid (casein), or a solution (sugar, albumin, and some salts), and these forms aid in making milk more digestible than some other solid foods.

In buying milk by the quart it is much more economical to purchase that which has a high solid content than that which does not. As a rule the percentage of fat is an index of the total solid content of milk because the solids not fat, increase as the fat increases, although not in the same proportion. Much has been said about the desirability of milk low in solids because for various reasons this milk is said to be better for infants than milk high in solids. If we grant this fact to be true, it does not follow for adult use that milk low in solid content is better than milk high in solid content. Infant feeding is a special case and such milk always has to be modified.

In Table 35[55] a quart of milk containing 3.5 per cent fat and 647.46 energy units (calories) was given a value of 12 cents, and this was taken as basis for computing the value of a quart of milk of various composition. A study of this table shows that if milk containing 3 per cent fat is worth 11.02 cents, one containing

[53] Atwater, W. O., Milk as a Food, U. S. Dept. of Agr., Farmers' Bull. No. 74.
[54] Milner, R. D., The Use of Milk as a Food, U. S. Dept. of Agr., Farmers' Bull. No. 363.
[55] Table worked out by J. D. Brew, Cornell University.

Table 35.—Energy Units and Cash Value of a Quart of Milk Containing Different Percentages of Total Solids.

Per cent fat.....	3.0	3.5	4.0	4.5	5.0	5.5	6.0
Per cent solids not fat.....	8.3	8.5	8.7	8.9	9.1	9.3	9.5
Energy units in fat in 1 quart	272.2	317.55	362.9	408.3	453.7	499.0	544.38
Energy units in solids not fat in 1 quart.....	331.9	339.91	347.9	355.9	363.9	371.9	398.5
Total energy units in 1 quart..	604.1	657.46	710.08	764.2	817.6	860.9	942.88
Value per quart.....	11.02	12.00	12.95	13.94	14.92	15.71	17.20

twice as much fat (6 per cent) is worth 17.20 cents, a difference of 6.18 cents per quart, based on its energy value.

VITAMINS IN MILK

The value of milk as a food was further recognized by the announcement of the discovery, in 1911, of a growth-promoting substance called a vitamin. This announcement was made by Casimir Funk, as a result of his work on beri-beri. However, for over ten years previous several investigators, chief among whom were Eijkman of Holland, and Hopkins of England, had been working on this subject and had noticed the curative effect of certain foods on beriberi. Since that time many of the leading scientists both in this country and Europe have devoted much time and energy to the question of vitamins. It is not possible to give here a list of all who have contributed to a knowledge of this important subject, but mention should be made of McCollum, Mendel and Osborn, Steenback, Hart, Jones, Sherman, Eddy and Sure.

Just what vitamins are cannot be definitely stated, and probably a vitamin in its pure state has never been extracted from the materials in which it occurs. Vitamins are best known by the results which they produce, or better still by the disastrous results which follow from a lack of them. They prevent or cure the type of ailments called deficiency diseases such as rickets, neuritis and scurvy.

It is not known how many vitamins there are and the discovery of new ones is being announced from time to time. In the two or three years immediately following Funk's announcement of his discovery the time and energy devoted to the study of vitamins was redoubled and it was pretty generally agreed that there were at least three. These were named as follows:

1. Vitamin A, called fat soluble A, because it was found in cer-

tain fats and was soluble in them. It was found in milk fat, egg yolk, cod liver oil, and to a slight extent in the yellow fat of animals and in the leaves of plants. This vitamin was also known as the antirachitic vitamin because it prevented rickets. Steenback, Hart, Jones, and Black,[56] have, however, concluded that the antirachitic factor, while it is fat soluble, is an entirely separate vitamin and makes up the fourth member of the group. It is known as vitamin D. They also suggest that we should speak of the fat soluble vitamin in the plural and not in the singular sense. Vitamin A is not destroyed by pasteurization temperatures, or even by boiling, under ordinary conditions. In the destruction of vitamin A by heat, the presence of oxygen plays a very important part. This fact is important in the hydronization of fats because no matter how rich the original fats might be in vitamin A, it might not be present at all in the final product on account of the oxygen present during the process of hydronization.

2. Vitamin B called water soluble B, or antineuritic vitamin. This vitamin seems to be the most widely distributed in nature of any of the others yet discovered. It is found abundantly in milk, green plants, and in the germs of seeds. Yeast is said to be rich in vitamin B, and probably this vitamin is the most widely distributed one in nature. Vitamin B is not destroyed by pasteurization.

3. Vitamin C or antiscorbutic vitamin. This vitamin does not seem to be as widely distributed in nature as are the other two. It is found in milk, and in some fruits and vegetables, especially oranges and tomatoes. Unfortunately it is easily killed by pasteurization temperatures and orange juice is always recommended to be fed with pasteurized milk. Some investigators claim that aging milk will destroy vitamin C.

4. Vitamin D. This fat soluble vitamin has already been mentioned in connection with vitamin A.

5. Vitamin E, or reproductive vitamin. This vitamin was discovered by Sure [57] and was found to be necessary to fertility and reproduction. It was found in polished rice, rolled oats, yellow corn, and Georgia velvet bean pod meal. Sure does not mention

[56] Steenback, H., Hart, E. B., Jones, J. H., and Black, A., Journal of Biological Chemistry, Vol. 59, 1923-24.

[57] Dietary Requirements of Reproduction by Sure, Barnett, Journal of Biological Chemistry, Vol. 58, 1923-24.

finding this vitamin in milk. With the exception of vitamin E, experimental work shows that milk is one of the most prolific and important sources of vitamins. However, the vitamins found in milk are obtained by the cow from the food eaten, so that the amount of vitamins in milk is dependent on the kind of food eaten.

MILK AS A SOURCE OF ENERGY

The discovery of milk fat as a prolific source of vitamins A and D has greatly increased its value as a food in the estimation of dieticians. In addition to this it is a source of energy. If we consider the energy of milk fat as 9 calories per gram and since there are 28.35 grams in one ounce avoirdupois, we have 255.15 calories in one ounce of milk fat ($9 \times 28.35 = 255.15$), or 4082.40 calories per pound of milk fat. In comparison with other fats, milk fat is easily digested. Langworthy and Homes compared [58] the digestibility of butter fat, lard, beef fat and mutton fat with the following results:

Table 36.—Coefficients of Digestibility of Different Fats.

Kind of Fat	Coefficient of Digestibility
Butter	93.9%
Lard	93.7%
Beef	88.9%
Mutton	80.5%

The authors concluded that butter fat is more completely assimilated than any of the other fats studied.

It is believed that fats of low melting points are more easily digested than those whose melting points are high. This is one of the reasons why milk fat, which has a low melting point (86° to 96.8° F.) is easily digested. Another reason given for the digestibility of milk fat is the fact that it is in the form of an emulsion and is therefore more easily assimilated by the digestive system.

Milk sugar is the chief carbohydrate of milk and from a food standpoint its chief value is the furnishing of energy. It is not as soluble as is cane sugar and for this reason is thought to be less irritating to the stomach. Lactose is also regarded by some investi-

[58] Langworthy, C. F., and Homes, A. D., Digestibility of Some Animal Fats, Bull. No. 310, U. S. Dept. of Agr.

gators to be necessary for the growth and development of certain types of organisms which prevent intestinal putrefaction.

The protein constituents of milk consist of the casein and albumin and together make up about 3.3 per cent of the composition of milk. The casein is in a state of very fine suspension while the albumin is in solution. When milk is taken into the stomach, the casein is precipitated by the gastric juice into more or less solid masses. This sometimes causes digestive troubles, and the fact that more of milk protein is assimilated when milk is eaten with other foods than when eaten alone is probably due to the breaking up of the curd into small particles. This enables the casein to be acted upon by the digestive juices.

The other proteid of importance in milk besides the casein, is the albumin. While present in small amounts it is important because it is in solution and therefore very easily digested. Albumin is important in infant feeding and whey which contains the albumin in solution is often added to infant foods to increase the protein content. Milk is valuable in a ration by making the protein from vegetable sources more available. According to Hart and Steenback [59] the protein from cereals will show only about 30 per cent efficiency—70 of the cereal protein is lost during the process of digestion. When the cereal is eaten with milk the efficiency of the cereal protein is increased to between 60 per cent and 65 per cent.

By referring to Table 34 it will be seen that the protein of milk is highly digestible, when compared with the protein in a mixed diet or from animal foods. Attention has already been called to the fact that more of milk protein is assimilated when milk is taken with other foods than when eaten alone. This is because of the mechanical action of other food in breaking up the particles of curd, thus making it easier for the digestive juices to act on the casein.

The protein of milk for some unknown reason is not as irritating to the system as is the protein from animal sources and it is said to prevent an acid condition of the blood.

While milk contains all of the digestible nutrients, it cannot for three main reasons be called a perfect food.

1. It contains too much water in proportion to its solid content.

[59] Hart, E. B., and Steenback, H., Milk Necessary for the Nation's Welfare, Wisconsin Bull. No. 291.

In order to obtain a sufficient supply of digestible nutrients and sufficient energy an adult would have to consume a large volume of milk. In other words, milk lacks energy in proportion to its volume. A working man is said to require approximately 3500 [60] calories per day. In order to furnish enough heat units approximately four quarts of milk would be required. In this connection the difference in energy value between milk high and low in total solids should be pointed out. A quart of milk containing 3 per cent fat and 8.3 per cent solids not fat would have an energy value of 604.1 calories (see table 35). A quart of milk containing 5 per cent fat and 9.1 per cent of solids not fat would have an energy value of 817.6 calories. It would require approximately 5.8 quarts of the former and 4.3 quarts of the latter to furnish the 3500 calories per day for a working man. This is a difference of 1.5 quarts.

2. The digestive system needs some bulk (other than water) to stimulate it and make it work properly. In other words, we cannot live and thrive on too concentrated a ration.

3. The protein present in milk is in too large a proportion to the carbohydrates. The nutritive ratio of milk is about 1:4, which is rather narrow for the average working individual. So far as the food value of milk is concerned, the energy and protein requirement of an individual must be studied at the same time. The average working man requires about 4.48 ounces of protein per day. If just enough milk is consumed to furnish this protein, the ration would be low in calories. If enough milk is consumed to supply the right number of calories, more protein would be supplied than the body needs. However, the fact that milk is high in protein makes it a valuable food in planning a diet. One of the most difficult problems with which the dietician has to deal, is the question of the proper amount of protein. It has already been pointed out that milk protein is less irritating to the system than protein from other animal sources. This fact, coupled with the large amount of protein in milk, makes it one of the best foods for increasing the protein in a ration. Table 40 gives the per capita consumption of fluid milk in different countries. Considering the high food value of milk and its importance in the diet, this consumption is very low. Dieticians

[60] Atwater, W. O., Milk as a Food, U. S. Department of Agriculture, Bulletin No. 74.

are urging the consuming public to use more milk and especially to feed more of it to children. It is recommended that children be fed not less than one quart of milk per day.

In this connection the value of skimmilk and the various milk products should be emphasized. There is no better or cheaper way of increasing protein in the diet than by the liberal use of skimmilk. However, because the fat has been removed from it, skimmilk is regarded as a poor article of diet. Perhaps another reason for its unpopularity as a food is, on account of carelessness in handling, its flavor has oftentimes been impaired. Cream is an excellent food since it contains all of the constituents found in milk. The fat is, however, far in excess of the other digestible nutrients. This gives cream two main values as a food, one as a source of energy and the other as a source of vitamin A. The following figures gives the value of cream as a food.[61]

Table 37.—Showing the Food Value of Cream.

	Water	Protein	Fat	Carbo-hydrates	Mineral Matter	Food Value per Pound
Cream	74	2.5	18.5	4.5	.5	880

It will be noticed that while cream is high in calories it is low in protein. On account of its low percentage of protein, cream when compared with milk is not considered an economical food. However, the fat in cream imparts to it such an agreeable flavor that people have been willing to pay for the extra cost of cream over that of milk.

The various products made from milk are excellent foods and this is especially true of the cheeses. They are all high in protein and since many of them are made from skim or partially skimmilk, they make an excellent and economical substitute for meat. This is especially true of cottage cheese, which can be easily made in the home.

The following table compares the food value of three common types of cheese.[62]

By studying this table it will be seen that cottage cheese is high in protein and carbohydrates and has a fair amount of mineral

[61] Milk and its uses in the home, U. S. Dept. of Agriculture, Farmers' Bull. 1359.
[62] Milk and its uses in the home, *loc. cit.*

Table 38.—Food Value of Three Types of Cheeses.

Kind	Water	Protein	Fat	Carbohydrates	Mineral Matter	Fuel Value per Pound
	%	%	%	%	%	%
American Cheddar	33.5	26.0	35.5	1.5	3.5	1950
Swiss	31.4	27.6	34.9	1.3	4.8	1950
Cottage	69.8	23.3	1.0	4.0	1.9	535

matter although it is rather low in heat units. The other two cheeses, Swiss and cheddar, are high in all digestible nutrients except carbohydrates and on account of the fat they have a high fuel value. Cheddar cheese is often called a concentrated food and this can be easily seen by referring to Table 34, and comparing the digestible nutrients in cheese with other food products. For example, comparing the different cuts of beef with cheese, it will be seen that cheese has far more energy than any portion of beef and twice as much as some of the cuts. Cheese has a high percentage of protein and fat and it contains carbohydrates which are entirely lacking in meat.

The following table (39) shows the per capita consumption of cheese in different countries for different years. It will be noted that while the United States does not have as small a per capita consumption of cheese as some other countries, yet it is toward the bottom of the list in this respect.

Table 39.—Average Per Capita Consumption of Cheese per Year in Different Countries.

Country	Year	Cheese Consumed
		Pounds
Switzerland	1914	26.4
Netherlands	1912	13.3
Denmark	1914	12.3
United Kingdom	1905	11.2
Germany	1912	9.5
France	1892	8.1
Norway	1910	7.1
Italy	1913	4.8
Australia	1913	4.8
United States	1909	3.8
United States	1919	4.2
Canada	1911	3.0
New Zealand	1914	3.0
Argentina	1913	2.0

Both from the standpoint of economy and from the standpoint of the high food value of cheese, more of it should be eaten than now is. It is the popular notion that cheese is rather indigestible but experimental work does not prove this to be the case.[63] Because of its high concentration of digestible nutrients, people are apt to overeat cheese and lay the cause of digestive disturbances to indigestibility of the cheese.

Buttermilk and the so-called sour milk drinks have high food value, but their digestible nutrient content varies according to whether they are made from whole or skimmilk. Their value as a food is also partly a medicinal one, due to the lactic acid present and the effect on the digestive tract of the bacteria used in souring the product. This will be discussed elsewhere.

Condensed milk and milk powder are high in all the digestible nutrients but as in the case of many manufactured dairy products, the content depends on the source of the product, whether they were made from whole or skimmilk.

The main uses of condensed and powdered milk have been in manufacturing ice cream and in cooking operations. It was never intended to substitute either of these products for whole milk where that product was obtainable. However, both condensed and powdered milk have been successfully used in some cases for infant feeding, and one company manufacturing powdered milk makes a specialty of powdered milk for infant and invalid feeding.

[63] Langworthy, C. F., and Hunt, Caroline, L., Cheese and its Uses in the Diet, U. S. Dept. of Agr. Bull. 487.

Table 40.—Per Capita Consumption of Whole Milk in Various Countries per Year.

Country	Year	Milk Consumed
		Gallons
Sweden	1914	69.7
Denmark	1914	68.5
Switzerland	1914	67.4
Germany	1913	61.0
Belgium	1895	44.0
United States	1917	42.4
United States	1920	43.0
Netherlands	1902	39.5
Canada	1916	26.0
Hungary	1914	24.3
United Kingdom	1914	22.2
Italy	1913	4.2
Hawaii	1916	1.0

Table 41.—Average per Capita Consumption of Butter in Various Countries per Year.

Country	Year	Butter Consumed
		Pounds
Canada	1911	27.7
Australia	1913	25.6
New Zealand	1914	21.7
Denmark	1914	19.0
United States	1909	17.5
United States	1919	15.5
United Kingdom	1914	17.0
Netherlands	1917	16.8
Sweden	1917	16.5
Germany	1913	14.7
Norway	1906	14.0
Switzerland	1914	12.1
Italy	1913	2.5
Argentina	1913	1.8

Chapter VIII

GRADES OF MILK

Whenever grades of milk are mentioned there are generally two things considered: first, the chemical composition, and second, the bacteria content. The chemical composition has to do with the value of milk as a food so far as its digestible nutrient content is concerned; and the second has to do with the value of milk from the standpoint of wholesomeness. The latter is by far the most important, for no matter how high milk is in total solid content, if it contains one disease-producing organism it is unfit for human consumption. The same would also be true if milk contained some adulterant or some preservative which was harmful to the human system.

While grading of milk very properly lays by far the greater emphasis on sanitary quality, it should not neglect chemical composition. Every encouragement possible should be given to have placed on the market milk of a high solid content, because volume for volume it contains more food than milk of a low solid content. In most of the larger milk-producing states there are laws regulating the minimum amount of total solids allowed in milk sold for market purposes. These regulations were necessary and have no doubt prevented fraud and adulteration of milk, but it cannot be denied that they have also had a tendency to lower the average chemical quality of milk. Within certain limits the cost of producing milk is in proportion to the total solids it contains and very naturally the producer has tended more and more to produce milk which is near the lowest legal limit. In many cases the producer cannot be blamed for doing this, since no incentive, financial or otherwise, has been given him to produce milk of greater food value.

In judging the sanitary quality of milk the numbers of bacteria are usually taken as an index of its fitness for human food. This is done because numbers of bacteria show whether the milk has been

produced and handled in a way which is in keeping with sanitary principles. Argument is often made that a differentiation should be made between the species of bacteria in milk and that it is unfair to keep milk from the market because it contains, for example, large numbers of lactic acid bacteria. While it is true that it would be desirable to differentiate between disease-producing and non-disease-producing organisms it would, on account of the time required and the expense involved, be a physical impossibility.

As a matter of fact when infected milk causes an epidemic the organism causing the particular disease is not always isolated from the milk. The small number of organisms in proportion to the large volume of milk would make this, to say the least, a difficult, if not almost impossible task. If, however, along the route of a certain milkman there suddenly occurs an outbreak of typhoid fever and it is found that some member of his household had the disease and upon the withholding of this milk from the market the epidemic ceases, there can be no question but what the epidemic was caused by typhoid fever germs being carried in the milk from the dairy in question. If milk continuously shows high bacteria counts it shows carelessness and inattention, either in production, or handling, or both. If someone producing or handling milk is careless he is liable to allow the entrance of disease germs into the milk.

A further argument in favor of the necessity of clean milk is the universal use made of it for infant feeding and as a food for young children. Milk may be highly contaminated with bacteria, which, strictly speaking, are not pathogenic. At the same time these bacteria may cause changes in the product which render it an unfit food for infants.

The economic side of clean milk production is also of prime importance to dairy industry. If milk were allowed to go on the market with a high bacteria count, it would soon spoil and the consumer would soon lose confidence in it as a human food. This would result in less of it being used and it is safe to say that the enormous demand for market milk would drop off to the extent of ruining our market for the product.

Clean milk is also necessary in the manufacture of the best grade of dairy products. Butter, ice cream, and the various kinds of cheese made from clean milk and cream invariably give better

satisfaction and command a higher price than when they are made from milk and cream of poor sanitary quality.

Serious outbreaks of various communicable diseases, such as scarlet fever, typhoid and diphtheria, have occurred in different parts of the country, and in many cases these diseases have been disseminated through the milk supply. The following instance reported by Frank [64] is a good illustration of the manner in which these outbreaks occur. In a certain town in which there was only an occasional case of typhoid fever there suddenly occurred an outbreak of the disease and this seemed to be in families taking milk from one dairy. Furthermore, the disease was restricted to those families taking milk in pint bottles only. After a thorough examination no one from the dairy furnishing milk to this locality was found suffering from the disease, but as cases continued to develop along the route of the particular dairy the supply was stopped and in about two weeks time new cases of typhoid ceased to appear. The fact finally came to light that a man from another city had visited the place where the epidemic occurred and had become ill with typhoid. At the house where he was staying there was supplied each day three pint bottles of milk and these were returned to the dairy and evidently were refilled and used without being sterilized and in this manner the disease was spread. There was a total of 28 cases of typhoid which developed in families taking milk from this particular dairy.

While it is true that several hundred cases more or less similar to the one described above have been noted and the data in regard to them tabulated, it ought not to be inferred that milk is generally a carrier of disease. When one stops to consider the enormous quantities of milk used as a human food and the small number of diseases transmitted by milk, it will be realized that the general milk supply is worthy of the confidence of the milk-consuming public. The danger of transmission of disease by means of milk should not be minimized, and everything should be done to keep the milk supply free from contamination. At the same time the transmission of disease by milk should not be overemphasized to a point where people lose confidence in it for the facts are far from warranting such a condition of affairs.

[64] Frank, John W., Milk as a Cause of Epidemics of Typhoid Fever, Scarlet Fever, and Diphtheria, Milk and its relation to the Public Health, Hygienic Laboratory Bull. No. 56.

Since numbers of bacteria are used as a basis for judging the sanitary quality of milk, it is only reasonable to expect that milk of good and poor sanitary quality should be limited by bacteria counts. In the case of certain grades of milk this is what is done, but sanitarians are very loath to state just what should be the bacterial limits of good milk, or how many bacteria per c.c. constitute poor milk. The argument is sometimes advanced that there can be but two possible grades of milk; namely, that which is fit for consumption and that which is not. While this argument has considerable logic, the question is not as easy to decide as one might at first suppose. Let us assume that 50,000 germs per c.c. are as many bacteria as good milk should contain; it would be very difficult to prove that milk containing 51,000 bacteria per c.c. is any worse for human consumption than milk containing 50,000 germs per c.c. However, we are justified in fixing bacterial limits for grades of milk. To use the illustration just cited, if it is the best judgment of persons who are qualified to hold an opinion that 50,000 bacteria per c.c. is as high a bacteria count as good milk should be allowed to have, it is proper to put this limit on good milk, for if no limits could be placed we could have no grading of milk. In other words, we must have a limit somewhere in order to make progress in clean milk production.

One of the most important grades of milk is pasteurized milk, and the importance of this grade of milk can be appreciated when we consider the large proportion of pasteurized milk which is sold in our large cities. This is well shown in the following table.[65]

Table 42.—Percentage of Pasteurized Milk in Four of Our Largest Cities for Year 1923.

Name of City	Average Daily Receipts (Quarts) 1923	Per Cent of Daily Receipts Pasteurized
New York	2,497,748	98%
Boston	588,206	96.72%
Philadelphia	710,417	98%
Chicago	1,000,000	99%

The universal practise of pasteurizing milk is further shown in Table 43, the figures of which were taken from U. S. Department

[65] The data in this table was furnished by the Boards of Health of the cities named in the table and their courtesy is hereby acknowledged.

Table 43.—Proportion of Cities Having Pasteurized Milk and Average per Cent of Their Milk Supply Which Was Pasteurized. Year 1921.

Population of Cities	No. of Cities Reporting Pasteurized Milk	No. of Cities With No Pasteurized Milk	Per Cent of Cities With Pasteurized Milk	Average Per Cent of Milk Pasteurized
More than 500,000	12	0	100	95
100,001 to 500,000	42	0	100	72
75,001 to 100,000	15	0	100	68
50,001 to 75,000	29	5	85	65
25,001 to 50,000	55	7	89	58
10,000 to 25,000	77	49	61	51
Less than 10,000	36	52	41	53
Total	266	113	..	..

of Agriculture Bulletin 342.[66] A study of this table shows that cities of all sizes are using more pasteurized than raw milk. As would be expected the larger cities have a higher percentage of their milk supply pasteurized than do smaller cities. This is probably true for three reasons, the first of which is that the larger cities are better equipped to inspect the milk supply and enforce pasteurization regulations. The second reason is that the large cities have such large milk supplies that the tendency is to have few milk dealers who handle large volumes of milk, and this makes compulsory pasteurization easier to enforce. In smaller cities much of the milk sold is peddled by the small producer and it would be economically impossible for such small producers to pasteurize their milk supply. To enforce a pasteurization ordinance would force them out of business.

In the case of small cities it is possible, because of the nearness of the supply, to furnish the consumer with milk which is comparatively fresh and this milk should therefore have a low bacteria count. However, as is clearly shown in Table 43, the smaller cities are finding it desirable to adopt pasteurization. The third reason why a large percentage of the milk supply of our bigger cities is pasteurized is because of the long hauls which are necessary to obtain a sufficient volume of milk. Proper pasteurization makes it possible, in a perfectly legitimate way, to furnish the consumer with

[66] Ayres, S. Henry, The present status of the pasteurization of milk, U. S. Dept. of Agr. Bul. 342.

a milk supply low in bacterial count. It is doubtful if this would be accomplished without pasteurization.

PASTEURIZATION

The process of pasteurization was first used in the beer and wine industry of France. A great deal of trouble was experienced by the French in having these products spoil through the action of yeasts and molds. While it was known that high temperatures would destroy the action of the yeasts and molds, it was also known that the degree of heat necessary to kill them would also change the flavor of the product and render it unsalable. Sometime in the early sixties, Louis Pasteur suggested that the beer and wine be heated to a comparatively low temperature for a comparatively long time. This suggestion was carried out with great success, and about twenty years later the process was applied to milk.

So far as its application to dairying is concerned, pasteurization consists in heating milk or cream to a temperature sufficiently high and for a time sufficiently long to kill most of the organisms in them. Sterilization consists in killing every living thing in and about an object and this pasteurization does not necessarily do. It aims to approach sterilization as near as possible with the time and temperature employed, and under proper conditions the modern pasteurizer will destroy about 98 to 99 per cent of the germs ordinarily found in milk. However, the number of germs remaining in pasteurized milk after the process is completed is a better guide to the efficiency of the method than is the percentage reduction. If raw milk contained a large number of bacteria per c.c., it would be easily possible to have a 99 per cent reduction of bacteria due to pasteurization and still have comparatively large numbers left in the pasteurized milk. Suppose, for example, that one sample of raw milk contained 5,000,000 bacteria per c.c. and another sample contained 500,000 per c.c. and both were pasteurized by the same machine which was 99 per cent efficient. In the first case there would be left in the pasteurized milk 50,000 bacteria per c.c., and in the second case 5,000 bacteria per c.c.

Pasteurization has for its purpose two main objects: first, killing pathogenic organisms, and second, checking germ growth. So far

as the healthfulness of the milk is concerned the first object is by far the most important. Many of our more common diseases such as typhoid, diphtheria and septic sore throat have been traced to an infected milk supply and since the germs causing these diseases are quite readily killed by pasteurization temperatures, the process tends to make milk more safe for human consumption.

While the strict definition of pasteurization does not mention cooling, yet cooling milk after pasteurization is a necessary part of the process. Since there are bacteria left in the milk after the heating process is completed, these bacteria will increase unless the milk is cooled to temperatures at which bacteria will not grow. Failure to properly cool pasteurized milk defeats the purpose of the process.

So far as the relation of pathogenic organisms to pasteurization is concerned, Bacterium tuberculosis has received the most attention. This is important both from the standpoint of infecting human beings with the bovine type of tuberculosis and also from the standpoint of spreading the infection among cattle. Some states have passed laws compelling milk plants to pasteurize skimmilk before selling it back to their patrons. Some persons who are opposed to pasteurization have pointed out that a well-enforced ordinance requiring all cows supplying milk for fluid milk trade to be tuberculin tested, would do away with the necessity of pasteurization. While tuberculosis may be transmitted by milk it is by no means the only disease of importance, and the importance of tuberculosis in respect to a clean milk supply should not blind us to the necessity of protecting the fluid milk supply against infection from other disease-producing organisms which may be milk-borne.

The second object of pasteurization, that of checking germ growth, is of great importance commercially. Milk which contains a fairly large number of organisms may have these germs killed by pasteurization, and thus the milk may be kept for a much longer time than would otherwise be possible. However, the process of pasteurization should never be used as a cure-all for dirty milk or as an excuse for putting on the market milk which has an abnormally high bacteria count. The process of pasteurization is intended to be an added safeguard and milk intended for pasteurization should be as clean and wholesome as though it was intended to be used in the raw state.

There are two main methods of pasteurization: one, called the holder method, and the other, the flash method. In the first method the milk is held at a comparatively low temperature for a long period of time, while in the second method a high temperature for a short time is employed. The temperature usually employed in the holder method is 145° F. for a period of 30 minutes, this time and temperature being considered sufficient to kill most pathogenic organisms which would ordinarily be found in milk. This time and temperature could not of course be depended upon to kill spore-bearing organisms. Higher temperatures and longer time of heating cannot be employed in pasteurizing milk because they would change its flavor and odor so that it would be objectionable to the customer. Higher temperatures and longer periods of time would also change the chemical composition of the milk, and render it more indigestible. Under some circumstances heating to a temperature of 145° for 30 minutes has interfered with the creaming of milk. This has been made the subject of considerable study, because it is of great importance commercially. If the customer does not see a cream line on the bottle of milk, it is at once inferred that the milk is poor in food quality although the absence of a cream line does not necessarily mean that the milk does not contain a fair amount of fat. Harding [67] found that a temperature of 143° F. reduced the cream line 10 per cent by volume, a temperature of 145° F. reduced it 16.6 per cent and a temperature of 148° F. reduced the cream line 40 per cent. The temperature of 143° F. is a very critical one so far as affecting the cream line on milk is concerned and when the fact is taken into account that it is very difficult to control the temperature of the pasteurizer to within two or three degrees, the temperature to which the milk is heated is a very important one.

Hileman [68] found, however, that raising the temperature for an instant to 148° F. did not affect the cream line, but raising the temperature from 145° to 148° for five minutes did affect the cream line seriously.

There are a number of factors in pasteurization besides the actual

[67] Harding, H. A., Effect of Temperature of Pasteurization on the Creaming Ability of Milk, Univ. of Ill. Bull. 237.

[68] Hileman, J. L., Thesis on the Effect of Pasteurization on the Creaming Ability of Milk, Cornell Univ., 1923.

process of heating which affect the cream line. Harding found that agitation of milk at low temperatures for a long time prevented fat from rising, and this fact is corroborated by Hileman. There are two factors found by the same investigator to be of prime importance in regard to the creaming ability of pasteurized milk. The first is to cool milk to a low temperature as soon as possible after heating. This will increase the amount of fat which will rise to the surface of the milk, even though the temperature of the milk is much higher during the period while the milk is creaming. The second point, which according to Hileman has the greatest influence on the amount of cream rising to the surface of pasteurized milk, is to hold the milk at as low a temperature as possible and not freeze it.

Hileman also found that a short cream line was due generally to failure of fat to rise, rather than to a shrinkage of the cream line itself. To prove this the same lot of milk was treated in ways which would vary the size of the cream line. Layers of the skimmilk below the surface of the cream line were then removed and in case of the samples showing a short cream line, the skimmilk contained more fat than did the skimmilk of the samples having a long cream line. In this connection it was also found that 25 c.c. of skimmilk drawn from just below the cream line contained more fat than 25 c.c. of skimmilk drawn from the bottom of the container.

Hileman also did considerable work which strongly indicated that the effect which pasteurization has on milk serum is as much responsible for the inability of milk to cream as is the effect on the fat globules. This in a general way was shown by pasteurizing cream and skimmilk separately and then mixing them in all possible ways to obtain combinations of raw and pasteurized cream and skimmilk. In every experiment tried, pasteurization of either the cream or skimmilk caused a reduction in cream line in the mixture and pasteurizing the skimmilk had nearly double the effect in reducing the cream as did pasteurizing the cream.

In the flash method of pasteurization, the milk is heated to a given temperature for a very short time, and this time is so brief that oftentimes some of the milk is not heated at all, which of course means inefficient methods so far as killing germs is concerned. For this reason many Boards of Health have forbidden the use of the flash method of pasteurization. When market milk is

pasteurized by the flash method a temperature of 160° to 165° F. is very commonly used, and a temperature much higher than this is liable to impart a cooked flavor to the milk. Flash pasteurization is often used in pasteurizing milk and cream for manufacturing purposes where high temperatures may be used without injuring the product, as, for example, pasteurizing cream for buttermaking.

An attempt has been made by some milk dealers to pasteurize milk in the bottle. The theory of this method is excellent for if milk could be placed in the final package and pasteurized without the necessity of further handling, it would do away with any chance of contamination after the process of pasteurization was completed. The trouble, however, experienced with this method is due to the coefficient of expansion of milk. When the bottle is filled full, the cap inserted and the bottle heated, the milk expands and oozes out around the cap, or else forces the cap out of the bottle. In either case this spoils the appearance of the package, and when the milk cools the volume of milk shrinks, and the bottle is not as full as it should be to hold the correct volume. There are two methods of getting around the difficulty of the expansion of milk in the bottle, neither of which is satisfactory. The first method is to fill the bottle level full and then pasteurize the bottles of milk, leaving the cap off and capping the bottles after the process of pasteurization is completed. This method to a certain extent defeats the purpose of the process, since capping the bottles after pasteurization allows a chance of contamination. This method is also wasteful, because the bottles are filled above the ring or stopple in order to make sure that the bottle will be full after the milk has shrunk on cooling.

The second method of meeting the difficulty is to have an oversized bottle, with space enough between the mark where the bottle is full and the cap to allow for the expansion of milk when it is heated. With a special cap which is made to stand the heat of sterilization the bottle may then be capped before pasteurization. The customer, however, has to be educated to the fact that the bottle holds the correct amount to a mark considerably below the cap and not to the cap itself. This is sometimes not an easy thing to do and is always troublesome and involves more or less expense.

In pasteurizing milk in the bottle two methods of heating may be used, one by means of hot water and the other by means of steam.

In one type of in-the-bottle pasteurizer which is on the market the crates of bottles are piled one above the other and trays fitted over the necks of the bottles. Hot water is then pumped into the top tray and the hot water flows through holes in the tray striking the bottle just under the lip. This hot water flows on down through the stock of bottles. Cooling is done by using cold water and finally ice water in place of hot water.

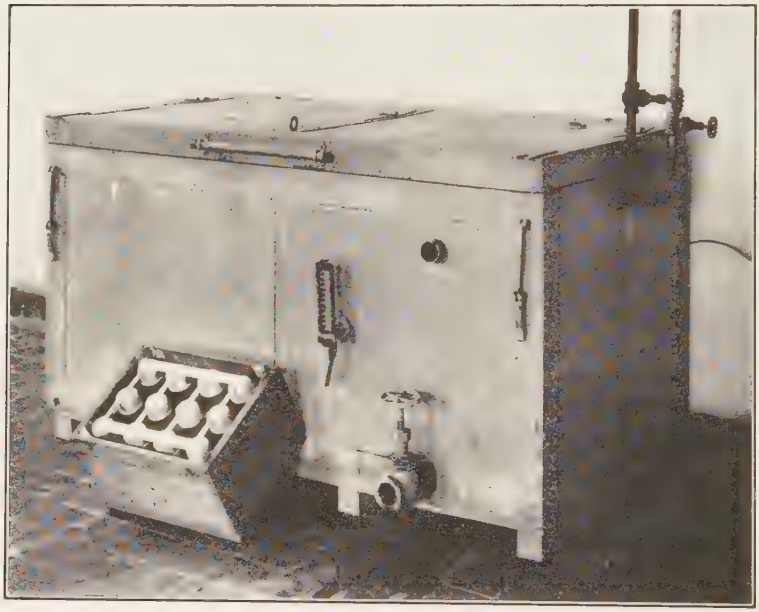

FIG. 7. Type of In-the-Bottle Pasteurizer Which Heats the Milk by Means of Steam.

In another type of in-the-bottle pasteurizer, steam is employed to heat the milk. The bottles are placed in the pasteurizer and are left uncapped. Over the tops of the bottles are placed metal caps. Steam is turned into the pasteurizer and the milk in the bottles is heated to the proper temperature for the proper length of time. After the milk has been heated for the proper length of time, the milk is cooled by turning cold water into the bottom of the machine and the bottles are gradually submerged. The cold water should not be allowed to enter the pasteurizer too rapidly as the sudden

change in temperature may increase bottle breakage. As the milk in the bottle cools it shrinks and this is said to form a partial vacuum in the bottle, causing the metal caps to fit so tightly over the lip of the bottle as to make a waterproof seal and thus preventing the water used in cooling from entering the bottles. In all types of in-the-bottle pasteurizers, it is absolutely essential that the water used in cooling or heating be kept out of the bottle, as this would dilute the milk and also might cause contamination of the milk and so render the process useless. For this reason, bottles which have a clipped edge are not safe to use in in-the-bottle pasteurizers of this type as they might not form a perfect water-tight seal with the metal caps.

The temperature of the milk should be taken from a thermometer having its bulb in the bottom of the bottle. Ayres and Johnson [69] have shown that in order to get correct temperatures it is necessary to extend the bulb of the thermometer nearly to the bottom of the bottle, as they obtained in some cases as much as 13° difference in temperature between the milk in the bottom and the milk in the top of a bottle. They also found that it took nearly ten minutes longer to heat the milk in the bottom of the bottle to a given temperature than it did to heat the milk in the top of the bottle to the same temperature.

Ayres and Johnson have also shown that, so far as reduction of bacteria is concerned, bottling pasteurized milk while hot gives good results, although this has never been tried on a commercial scale. Best results were obtained from the standpoint of reduction of bacteria when the bottles were steamed previous to filling. This not only tended to sterilize the bottles, but it also brought the temperature of the bottles approximately up to the temperature of the hot milk and this tended to reduce bottle breakage.

The advantages of pasteurizing milk in bottles may be summed up as follows:

1. When the bottles are capped before pasteurization it renders the chance of contamination almost negligible.

2. Providing the capacity of the pasteurizer is large enough, the pasteurized milk may be stored ready for market in the machine until time of delivery.

[69] Ayres, S. H., and Johnson, W. T., Pasteurizing Milk in Bottles and Bottling Hot Pasteurized Milk, U. S. Dept. of Agr. Bull. 240.

3. It is easily possible for the bottles to receive a second sterilization.

The disadvantages are as follows:

1. Special oversized bottles are needed to allow for expansion of milk.

2. Special caps must be used.

3. Unless extreme care is taken there is large bottle breakage.

4. The oversized bottle, special cap and bottle breakage increase the cost of pasteurization.

5. Requires more heat than bulk pasteurization, as the bottle must be heated.

6. More space is required for a given amount of milk than in bulk pasteurization, on account of the bottles.

Unfortunately, the results obtained in pasteurization are not always uniform, and the following are some of the chief causes for the variable results obtained.

1. Kind of bacteria present. If the germs present are spore-bearing, they will be much more resistant to heat and larger numbers will remain after pasteurization than if the bacteria were non-spore-bearing. The same would be true of any heat-resisting organisms whether they were spore-bearing or not, e.g., those surrounded with a capsule.

2. The number of bacteria present. If due either to age or high initial contamination there are large numbers of bacteria present, a machine with a given percentage efficiency will leave more bacteria in the milk than if there were a few bacteria present.

3. Length of time the milk is heated. The longer time the milk is heated the more bacteria are killed, although milk cannot be heated for too long a time because of its effect on the flavor and odor of milk.

4. Temperature to which the milk is heated. The higher the temperature the more bacteria are killed. The degree of heat is, however, limited because of the effect of too high temperatures on the flavor and odor of milk.

5. Thoroughness of the process. By this is meant the care and accuracy with which the process is carried out. Under this heading might be included the condition of the pasteurizer, proper degree of heat, sufficient length of time, prevention from infection, both

during the process of heating and after the process was completed, and proper cooling of the milk after the heating process is completed.

There are several arguments in favor of and against pasteurization. Those in favor of pasteurization are as follows:

1. When properly done it kills pathogenic organisms and so renders the milk safe from transmitting disease. This of course assumes that the milk is not reinfected after pasteurization.

2. It checks germ growth and prevents spoilage. This tends to make pasteurization an economical measure.

3. It produces a uniform product. This is a very essential factor in dairy products of all kinds.

4. It increases confidence in milk and so encourages its use.

The following are arguments against pasteurization:

1. The process is costly. Just what the exact cost is can only be determined in each individual case. Fuel, refrigeration and labor are all plentifully required in pasteurization, and the price of all of these vary greatly in different sections of the country and under different circumstances. According to data published by John T. Bowen, U. S. Department of Agriculture, Bulletin 85, the cost of pasteurizing milk under certain given conditions was .00313 cent per gallon, and the cost of pasteurizing cream under similar conditions was .00634 cent per gallon. These figures were based on 1913 prices and to meet the changes due to increased costs, Bowen [70] has revised his figures, giving the cost of pasteurizing milk as .0049 cent per gallon.

2. It kills germs but does not necessarily destroy their products. In other words, it makes possible the placing on the market milk which has been highly contaminated and which was on the verge of spoiling at the time it was pasteurized.

3. It may make the producer careless. If the milk producer knows that milk which he produces is going to be pasteurized he might not withhold from the regular market supply milk which for any cause might be highly contaminated.

4. It may induce a feeling of false security in the product. This is particularly true in the case of the consumer, since many of them feel that because the milk is pasteurized it does not have to be kept cold like ordinary milk.

[70] Bowen, J. T., quoted by S. Henry Ayres in U. S. Dept. of Agr. Bull. 342.

5. It may cause chemical changes in the milk. There seems to be no question but what milk heated to a reasonably high temperature, e.g., around 68.3° C. (155° F.) is changed in its chemical composition. Around this temperature some of the albumin is coagulated, and as the temperature is increased larger quantities of albumin are precipitated. According to Rupp [71] at a temperature of 71.1° C. (160° F.), 30.78 per cent of the milk albumin is coagulated. The same author states that in the case of milk heated to a temperature of 75° C. (167° F.) the time required for the coagulation of milk by rennet is almost doubled when compared with the time required to coagulate whole milk. This indicates that the mineral constituents which are in close combination with the casein of the milk are rendered more insoluble by heat.

If milk is heated to a high temperature the calcium and magnesium salts are changed to more insoluble forms and if milk is heated to boiling temperatures for some time the sugar and casein are caramelized. This is indicated by the brown appearance of the milk.

Another change effected by heat is the killing of the enzymes in milk. Different authorities give different temperatures at which the several milk enzymes are destroyed, but it is quite generally agreed that most of them are killed at temperatures ranging from 70° C. to 85° C. (158° F. to 185° F.).

The question of the effect of pasteurization temperatures, 145° F. for 30 minutes, on the chemical composition of milk is one which has given rise to all sorts of conflicting testimony and is a question which has never been definitely settled. The main points under dispute are those which involve the coagulation of the albumin and the rendering of the calcium and magnesium phosphate insoluble. So far as has been determined there is no evidence to show that either the albumin or the calcium or magnesium salts are affected by a temperature of 145° F. for 30 minutes. There seems to be no question but what vitamin C may be killed by this temperature under ordinary conditions of pasteurization.

Beginning in April, 1911, G. M. Oyster,[72] a milk dealer of Washington, D. C., established at his own expense baby-feeding stations. These stations were under the supervision of a board of 20 physicians

[71] Rupp, Philip, Chemical changes produced in cows' milk by pasteurization, U. S. Dept. of Agr. Bull. 166.

[72] Report of G. M. Oyster, Baby Milk Philanthropy, by I. C. Weld.

and trained nurses were employed to take charge of the infants and give directions in regard to their care.

In addition to different formulæ prescribed by the physicians, 208 of the infants were fed on raw milk and 111 on pasteurized milk. Those receiving pasteurized milk made an average gain of .4274 ounces per day while those receiving raw milk made a gain of .4253 ounces per day. This is an average gain of .0021 ounces per day in favor of those fed pasteurized milk.

Park and Hall [73] in studying groups of infants in different sections of New York City found that during the hot summer months infants fed on pasteurized milk usually did better than those fed on raw milk. This was especially true if the raw milk contained large numbers of bacteria per c.c.

6. The cream line is sometimes diminished by pasteurization temperatures.

The statement is often made that bacteria will grow better in pasteurized milk than in raw milk. There does not seem, however, any proof that this is the case. What is more likely to be true is the fact that there are so few species left after pasteurization that those which do remain have a chance to grow unhindered by other species.

The bacteria which are left in milk after pasteurization has been carefully studied by Ayres and Johnson.[74] Those found in raw milk were divided into four groups; namely, the inert, the acid-producing, the alkali-producing and the peptonizing groups. In raw milk the inert group is by far the largest. The acid group was subdivided into two groups, those which coagulated the milk rapidly and those which required more than 14 days to coagulate milk. It was found that the temperature to which milk was heated had a great influence on the relative size of the groups left after pasteurization. At the temperature to which milk is commonly pasteurized, namely, 145° F. for 30 minutes (62.8° C.), both the acid and the acid coagulating groups increase in proportion to the others. As the temperature is increased the group which produces acid slowly increases and the alkali and peptonizing groups are reduced to a minimum. When the temperature is raised to 180° F. (82.2° C.) the peptonizing group increases to 75 per cent of those which survive pasteurization.

[73] Park, W. H., and Hall, L. E., Medical News, vol. 83, pg. 1066.

[74] Ayres, S. Henry, and Johnson, Wm. T., A study of the Bacteria which Survive Pasteurization, U. S. Dept. of Agr. Bul. 161.

According to Ayres there are two classes of streptococci which survive pasteurization; namely, those having a low thermal death point and those having a high thermal death point. In the former case only a few survive pasteurization and the latter group are those responsible for the high streptococci which are associated with diseases belonging to the group which have a low thermal death point.

There has recently been put on the market a machine for pasteurizing milk by means of electricity. The machine consists of a metal chamber in the bottom of which are two poles which are connected with an electric current. The milk runs between these poles and forms a connection between them, but on account of the high resistance of milk to an electric current heat is generated. It is this heat which is responsible for the destruction of bacteria in the milk. Since it takes only a few seconds for the milk to pass through the chamber the process is essentially one of flash pasteurization.

Chapter IX

GRADES OF MILK (*Continued*)

CERTIFIED MILK

Certified milk is milk that is produced under the supervision of a medical milk commission.

A medical milk commission is appointed by a county medical society and it is recommended that the milk commission consist of at least five members. It is the duty of the commission to look after and be responsible for: (1) the sanitary condition of the dairy so far as the production of milk is concerned; (2) the veterinary inspection of the herd; (3) the health of the employees as revealed by medical inspection; and (4) the chemical and bacteriological examination of the milk.

Milk is one of our best foods, and in producing certified milk it is the purpose to have this food furnished in as pure a state as it is humanly possible to have it furnished.

The idea of certified milk production originated with Dr. Henry L. Coit, a physician of Newark, N. J. The Medical Society of New Jersey in the year 1889 made a careful survey of the milk supply of that state and found it unsatisfactory. They appealed to their state for aid in having the milk supply improved but were unsuccessful and Dr. Coit conceived the idea of certified milk production. He at once had the approval of his brother physicians and the first medical milk commission was formed April 13, 1893, and was called The Medical Milk Commission of Essex County, New Jersey.

The first dairyman to undertake certified milk production was Stephen Francisco of Montclair, N. J., who after beginning the production of certified milk was for the rest of his life an enthusiastic and successful producer. Toward the latter part of his career, Mr. Francisco for several years maintained a herd of 750 cows, all for the production of certified milk.

Since certified milk is a high grade product, dairymen who had no right to do so began to use the term "certified," and in order to protect the product, Mr. Francisco had the word "certified" registered in the U. S. Patent Office. This patent was granted on October 16, 1904, and bears the registry number 25368.[75] In order to protect the certified milk industry some of the states have passed laws protecting the word "certified" and have definitely stated that certified milk shall bear the name of the Commission certifying it.

When the production of certified milk first began and medical milk commissions in different parts of the country began to function there was little uniformity in their methods. This was very confusing, since certified milk in one section of the United States would mean quite a different product in another part of the United States. In order to unify and standardize methods there was organized in 1907 the American Association of Medical Milk Commissions. One year later, in 1908, there was organized the Certified Milk Producers' Association. These two associations working in unison have greatly furthered the cause of certified milk, and have gradually unified rules of production until they are practically the same the country over.

Under their direction certified milk has come to mean:

1. Milk drawn from healthy cows.
2. Kept under clean and sanitary conditions.
3. Cows fed wholesome food and pure water.
4. Milk handled by clean and healthy persons.
5. Milk drawn in clean atmosphere.
6. Milk drawn into clean sterile pails.
7. Milk handled in clean sterile utensils in as sanitary a way as possible.
8. Milk cooled to a low temperature as soon as drawn and kept cold until delivered.

While the standards set up by one commission do not necessarily bind the actions of another, yet the requirements of production are so uniform that the maximum number of bacteria allowed in certified milk is usually fixed at 10,000 germs per c.c. and the fat requirement is usually 4 per cent. As a matter of fact, however, the rivalry

[75] Kelly, Ernest, Medical Milk Commissions and Certified Milk, U. S. Dept. of Agr. Bull. No. 1.

among certified milk producers is so keen that the bacteria count of the milk from some farms seldom goes above 2,000 or 3,000 germs per c.c. and individual counts are sometimes obtained of 100 bacteria per c.c. Instances are on record where an individual plate made from certified milk showed no growth of bacteria at all.

The number of dairies certifying under different commissions varied from one to about 18, and some of the commissions certify to about 15,000 quarts of milk per day.

The medical milk commissions are supported in various ways. The members of the commission serve without pay but there are always expenses to be met in employing chemists, bacteriologists, veterinarians, advertising, etc. Sometimes the commission is supported by one person as a philanthropic enterprise. Other methods of raising funds are taxing the dealers a certain amount according to the amount of product handled, taxing the dairyman and selling sterile milk caps to the producer.

While certified milk was intended primarily for infant and invalid feeding, its use is now being broadened [76] and it is served in many homes, restaurants, and diners. At the present time (1924) there are 80 medical milk commissions and one hundred and fifty certified milk farms in the United States. The product furnished by these farms constitutes about 2 per cent of all milk sold.

Questions are often asked in regard to profits made from certified milk production. Like every other line of industry, some producers find certified milk production profitable and some do not. While certified milk usually retails for twice the market price of ordinary milk, its production is very costly. Since all of the cows in a certified milk plant must be free from disease, the maintenance of a healthy herd is of itself a big item of expense.

In addition to making it possible to purchase the very highest grade of market milk, certified milk production has been valuable from the standpoint of example. It has placed a high ideal toward which the ordinary market milk producer could work, even though he could not attain it. Many of the certified milk producers have been men who could financially afford to carry on experimental work in regard to the effect of certain practises on clean milk production.

[76] The following information furnished by Dr. R. R. Ferguson, Sec. of Am. Association of Medical Milk Commissions Courtesy, for which is hereby acknowledged.

By doing this these men have found out the things which were important in producing milk of low bacteria count and the ordinary milk producer could benefit by this information.

INSPECTED MILK

In connection with certified milk should be mentioned inspected milk because the production of this grade of milk is sometimes supervised by a medical milk commission. While the commission does not put its seal on such milk, the product is of a high grade, usually above ordinary market milk. The requirements for its production may of course be anything which the commission may demand.

Sometimes certain milk dealers or individual producers put out a grade of milk which they call inspected milk. In such cases there is no uniformity in what the term may indicate. The methods and rules of production might vary in each individual case.

MODIFIED MILK

Modified milk is milk so changed in composition as to meet the needs of infants and invalids. The basis of modified milk is cow's milk, and then the natural constituents are varied in proportion, and other ingredients added, to suit the individual needs. In one way modified milk serves a dual purpose—that of a food and that of a medicine.

The first modified milk laboratory was started in Boston, in 1891, by G. H. Walker, G. E. Gordon, and J. H. Waterhouse. This seemed to fill a long felt want among medical men and in the course of time laboratories were established in many of the leading cities of the United States and Europe.

The laboratory usually consists of three main rooms, an office, the modifying room, and a washing and sterilizing room. Modified milk is put up and sold on the prescription of a physician, the same as a prescription at a drug store. The office is the place where these prescriptions are checked over and recorded, and where necessary directions in regard to filling them are given.

In the modifying room are all facilities for filling prescriptions. Inasmuch as many of the modifications are alike, it is possible to keep on hand stock solutions of different materials, such as lime

water, both cane sugar and milk sugar solutions, cream of different percentages of fat, and barley water. Facilities are also provided for pasteurizing or sterilizing the prescriptions if desired. The wash room is the place where all of the containers are washed and sterilized. It is usually kept as distinct as possible from the modifying room, so that if any of the containers have been returned from sick rooms where there are infectious, contagious diseases, there will be no chance of spreading the contamination. The modified milk which is intended for infant feeding is put directly into the nursing bottles. This has the advantage of making it unnecessary to change the milk from one container to another and so run the risk of contamination, and also each bottle holds the correct amount for each feeding. The nursing bottles are easily packed in ice, and since they contain only a comparatively small amount of milk, they will, when packed in ice, drop to a low temperature very rapidly.

Milk for use in modified milk laboratories must fulfil the following conditions:

1. It must be fresh to avoid chemical change.
2. It must be drawn from healthy animals.
3. It should be from the mixed milk of a herd rather than from a single animal. Herd milk is usually more uniform in composition as the daily variation in the milk of one individual is quite apt to be offset by the variation in the milk of another individual.
4. The milk must be absolutely clean and as free from bacteria as it is possible to have it.
5. Animals must be fed on healthy food.
6. Transportation to the laboratory must be as short a distance as possible.
7. The milk supply must always be under the complete control of the laboratory.

There are many different formulas used in preparing modified milk for infant feeding. These can be used, however, only as a general basis as the individual requirements of infants are very variable. The formula which would agree with one infant would be almost fatal in some cases if fed to other infants for any considerable length of time. The only way in which the proper formula can be determined is to try different ones until the one on which the infant thrives best is found.

The difference in the formulæ used is well illustrated in the two following taken from Bulletin 41 of the U. S. Marine Hospital

Service. Both formulæ were recommended by Dr. Rowland G. Freeman.

Formula I.

Milk	Ounces	64
Lime water	"	4
Milk sugar	"	6
Filtered water	"	60

Formula II.

Cream (16 per cent)	Ounces	16
Fat free milk	"	16
Milk sugar	"	6.5
Lime water	"	6.0
Filtered water	"	90.0

In Table 44 is given the composition and the amount of milk to be fed to infants of various ages. The exact composition desired can be obtained only by accurate methods of standardization, such as is done by a modifying laboratory.

Table 44.—Schedule for Milk Modification for Various Ages.

(Dr. J. W. Schereschesky, Bull. 56, U. S. Marine Hospital Service.)

Age	Fat	Sugar	Protein	Quantity at One Feeding		Number of Feedings in 24 Hours
				Ounces	Grams	
Premature infants	1.00	4.00	0.25	¼– ¾	7– 22	12–18
First to fourth day	1.00	5.00	0.30	1 – 1½	30– 45	6–10
Fifth to seventh day	1.50	5.00	0.50	1 – 2	30– 60	10
Second week	2.00	6.00	0.60	2 – 2½	60– 70	10
Third week	2.50	6.00	0.80	2 – 3½	60–110	10
Fourth to eighth week	3.00	6.00	1.00	2½– 4	75–125	9
Third month	3.00	6.00	1.25	3 – 5	90–155	8
Fourth month	3.50	7.00	1.50	3½– 5½	110–170	7
Fifth month	3.50	7.00	1.75	4 – 6	125–185	7
Sixth to tenth month	4.00	7.00	2.00	5 – 8	155–250	6
Eleventh month	4.00	5.00	3.00	7 – 9	220–280	5
Twelfth month	4.00	5.00	3.00	7 – 9	220–280	5
Thirteenth month	4.00	4.00	3.50	7 –10	220–310	5

Home modification is often practised, but this should be done on the advice of a physician, and in order to do this successfully it is necessary for him to know as accurately as possible the composition of the milk. The percentage of fat can in most cases be quite easily determined and this alone will be of great aid in modifying milk.

In the home modification of milk it sometimes becomes necessary to pasteurize the milk. This had best be done in a water bath to prevent the milk from being scorched, and it is also much easier to control the temperature than when milk is heated directly over a flame or on a hot stove. For this purpose a double boiler such as is commonly used in culinary operations for cooking rice, tapioca and chocolate will be found useful. Another method is to place a couple of bricks or similar objects in a ten quart pail, and set the dish in which the milk is to be heated, on the bricks. Water should

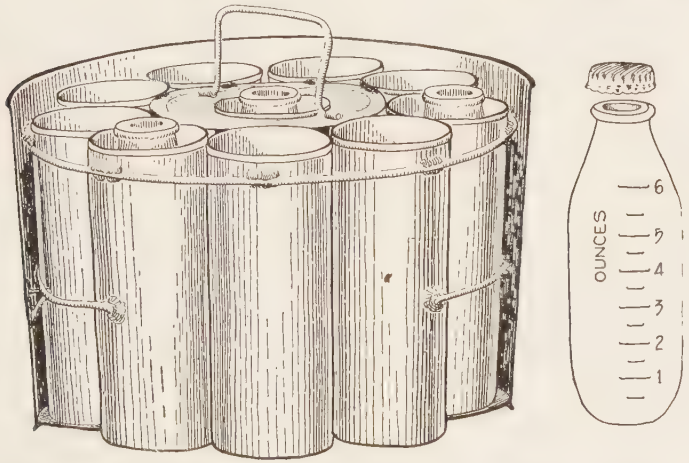

Fig. 8. Freeman Pasteurizer for the Home Pasteurization of Milk.

be added to the ten quart pail until the level of the water is slightly above the level of the milk in the dish. The milk may then be heated on a hot stove without fear of scorching. The object of the two bricks is to prevent the dish containing the milk from bumping while it is being heated. The milk should be frequently stirred while being heated.

Figures 8 and 9 show two types of apparatus which may be used for the home pasteurization of milk.

Milk of 3 per cent fat is very frequently used as a basis for milk modification, and Table 45 gives the amount of cream it would be necessary to remove from a quart bottle of milk in order to reduce the fat content of the remainder of milk in the bottle to 3 per cent.

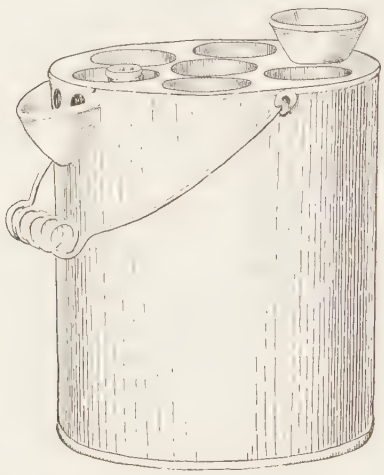

FIG. 9. Wilmot-Castle Pasteurizer for the Home Pasteurization of Milk.

The results obtained by this method will, however, be only approximate as there is a great difference in the creaming ability of different samples of milk.

Table 45.—Amount of Cream to Be Removed from the Top of a Quart Bottle of Milk of Different Percentages of Fat, in Order to Reduce the Percentage of Fat in the Remainder to 3 Per Cent.
(Schereschesky, Dr. J. W., Bull. 56, U. S. Marine Hospital Service.)

ORIGINAL PERCENTAGE OF FAT IN MILK	QUANTITY OF CREAM TO BE REMOVED FROM TOP OF QUART OF MILK AFTER CREAM HAS RISEN TO REDUCE FAT IN BOTTLE TO 3 PER CENT
4.00	50 c.c. or 1⅔ ounces
4.50	75 c.c. or 2½ "
5.00	100 c.c. or 3⅓ "

In some instances condensed milk, both plain and sweetened, has been used with success in infant feeding. Attention has already been called to the fact that one company manufacturing powdered milk makes a specialty of preparing one brand of their product for infant feeding and it is apparently being used successfully. Malted milk has been used for a long time in feeding infants. In some cases the above mentioned milks are not used alone but are mixed with a high grade of fresh milk. All pediatricians are very emphatic in

urging that all infants, so far as is possible, be breast fed. Campaigns have been carried on in various cities to induce mothers to nurse their infants instead of weaning them and feeding modified milk.

It has been pointed out by various authorities that the universal practise of nursing infants instead of feeding them artificially would greatly reduce infant mortality. This does not, however, lessen the importance of modifying milk for infant feeding. There will always be cases where, for pathological reasons, it will be impossible for mothers to nurse their infants and at weaning time the infant has to be fed on modified cow's milk, at least for a time.

SPECIAL GRADING OF MILK

In addition to the above-mentioned grades of milk some companies and milk dealers put out milk under special names, such as "Baby Milk," "Special Milk," "Grade A or B Milk," "Inspected Milk," "Sanitary Milk," "No. I Milk," etc. These names are used to emphasize the fact that the particular brand of milk is extra good, both as regards its sanitary quality and its chemical composition. Many companies do put out very fine grades of milk under these special names. It should, however, be borne in mind by the consumer that these names are more or less local and that a certain grade of milk in one locality may mean an entirely different grade in another locality. For example, the term "inspected milk" might have a certain significance in one state, while in another state the quality of milk sold under the same name might be an entirely different product.

Rules governing the production of market milk have grown up gradually. These rules have been added to and revised from time to time, as those who had their enforcement in charge saw the need. This means that a great many different individuals have contributed to our knowledge of how clean milk should be produced and, as might be expected, many divergent opinions have been brought forward. However, the main and fundamental principles of clean milk production are applicable everywhere. For this reason rules and regulations governing milk production are much the same the country over, differing mainly in minor points and also differing in methods of application.

With this idea in view there are given in the following pages the rules and regulations enforced by the New York State Department of Health, governing the production of market milk in New York State, where the milk is sold in municipalities.

These rules are given for the following reasons:

1. Although it is true that they apply to only one section of the country, they are typical of rules and regulations governing the production of milk for city consumption.
2. The rules and regulations are reasonable.
3. The rules and regulations have been in force for a number of years and are apparently successful.

The Sanitary Code established by the Public Health Council of the State of New York, Chapter III, governing milk and cream, is reproduced on pages 118 to 124 inclusive.

Chapter III

Milk and Cream

(Adopted June 16, 1914)

Regulation 1. Permit required for sale of milk in municipalities. No corporation, association, firm or individual shall sell or offer for sale at retail, milk or cream in any municipality without a permit from the health officer thereof, which shall be issued subject to such conditions as may be imposed by this code or by the local health officer except that the local health officer may exempt from the provisions of this regulation, persons selling milk from not more than one cow. Such permit shall expire on the thirtieth day of April, unless another date is designated by the local health board, and shall be renewable on or before such date in each year, and may be revoked at any time for cause by the state commissioner of health or the local health officer after a hearing on due notice. (Amended October 1, 1914 and December 7, 1920.)

Regulation 2. Application for permit required. No permit for the sale at retail of milk or cream in any municipality shall be issued unless written application has been made therefor in the form prescribed by the state commissioner of health. (Amended October 1, 1914 and December 7, 1920.)

Regulation 3. Information required in application for permit. Every application for a permit to sell at retail milk or cream in any municipality shall contain the name of each producer from whom the applicant receives or expects to receive milk or cream for sale, together with the approximate amount of milk or cream to be furnished by each such producer, and upon change in the source or amount of supply notice thereof shall be given promptly to the local health officer. (Amended October 1, 1914.)

Regulation 4. Dairy farms to be inspected and scored. Each health officer or his representative shall make a sanitary inspection and scoring of

every dairy farm where milk or cream is produced for sale at retail within his district, at least once in every twelve months and between November first and April thirtieth unless another date is designated by the local health board pursuant to regulation 1 of this chapter.

The local health officer of such municipality may, however, in his discretion, accept the inspection and scoring by the health officer or his representative of another municipality. (Amended October 1, 1914 and December 7, 1920.)

Regulation 5. Conditions of issuance of permit. On and after the first day of January, 1915, no permit to sell at retail milk or cream in any municipality shall be issued unless the premises, where it is proposed to handle such milk or cream, shall, in the opinion of the local health officer or his representative after inspection, have been rendered clean and sanitary: and unless each farm or dairy, where such milk or cream is produced, shall have been rated after inspection by a health officer or his representative, or, in case of protest, by a sanitary supervisor of the state department of health, at least forty per cent on the scorecard prescribed by the state commissioner of health. (Amended October 1, 1914.)

Regulation 6. Conditions of renewal of permit. No permit to sell at retail milk or cream in any municipality shall be renewed unless inspection has been made within the preceding six months by the local health officer or his representative of the premises where such milk or cream is handled and unless each farm or dairy where such milk or cream is produced has been rated by a health officer or his representative, or, in case of protest, by a sanitary supervisor of the state department of health, within the preceding six months after inspection at least forty per cent on the scorecard prescribed by the state commissioner of health. (Amended October 1, 1914.)

Regulation 7. Public display of permit. Permits to sell milk or cream shall be publicly displayed in such manner as may be prescribed by the local health authorities. (Amended October 1, 1914.)

Regulation 8. Milk and cream to be kept only under sanitary conditions. No milk or cream shall be sold or kept for sale under any conditions which in the opinion of the local health officer are not clean and sanitary.

All vessels containing such milk or cream for sale shall at all times be covered, kept cool, and so placed that the contents will not be exposed to sun, dust, dirt, flies, or other insects.

Regulation 9. Conditions of bottling of milk and cream. No milk or cream shall be served or sold in bottles or offered for sale in bottles, unless the bottling is done under clean and sanitary conditions at the place of production or collecting or distributing station.

Each bottle shall be capped and each cap shall show the name of the producer or dealer and the place of bottling.

Regulation 10. Receptacles to be kept in sanitary condition; when to be condemned and seized. Every can or other vessel, which is used to contain milk or cream or ice cream intended for sale, shall be constantly kept in a clean and sanitary condition. When emptied and before being returned by the person to whom it was last delivered full or partly full every such can or other vessel shall be effectively cleansed. The local health officer or his representative shall condemn any such can or other vessel found by him to be in such condition that it cannot be rendered by washing clean and sanitary as a receptacle for milk or cream, or ice cream, and shall destroy or

so mark the condemned vessel as to show that it has been condemned. When so condemned and marked, such can or other vessel shall not be used again to contain milk or cream, or ice cream for sale. The local health officer or his representative may seize and hold as evidence any can or other vessel returned or otherwise used in violation of this regulation. (Amended May 14, 1918.)

Regulation 11. Utensils to be cleansed. All dippers, measures or other utensils used in the handling of milk or cream, or ice cream intended for sale shall be maintained in a cleanly condition. (Amended May 14, 1918.)

Regulation 12. Pasteurization. Except where a different standard of pasteurization has been adopted previous to the first day of September, 1914, by the local health authorities, no milk or cream shall be sold or offered for sale as pasteurized unless it has been subjected to a temperature of 142 to 145 degrees Fahrenheit for not less than thirty minutes, and under such sanitary conditions as may be prescribed by the state commissioner of health; and no milk or cream which has been heated by any method shall be sold or offered for sale unless the heating conforms to the provisions of this regulation.

After pasteurization the milk or cream shall be immediately cooled and placed in clean containers and the containers shall be immediately sealed.

No milk or cream shall be pasteurized more than once. (Amended October 5, 1915 and December 7, 1920.)

Regulation 13. Designations of milk and cream restricted. All milk sold and offered for sale at retail, except milk sold or offered for sale as sour milk under its various designations, shall bear one of the designations provided in this regulation, which constitute the minimum requirements permitted in this state.

No term shall be used to designate the grade or quality of milk or cream which is sold or offered for sale, except:

"Certified"
"Grade A raw"
"Grade A pasteurized"
"Grade B raw"
"Grade B pasteurized"
"Grade C raw"
"Grade C pasteurized"

Certified. No milk or cream shall be sold or offered for sale as "Certified" unless it conforms to the following requirements:

The dealer selling or delivering such milk or cream must hold a permit from the local health officer.

All cows producing such milk or cream must have been tested at least once during the previous year with tuberculin, and any cow reacting thereto must have been promptly excluded from the herd. The reports of such tuberculin tests must be filed with the local health officer and the milk commission of the county medical society in the municipality and county respectively in which such milk is delivered to the consumer.

Such milk must not at any time previous to delivery to the consumer contain more than 10,000 bacteria per cubic centimeter and such cream not more than 50,000 bacteria per cubic centimeter.

Such milk and cream must be produced on farms which are duly scored

on the scorecard prescribed by the state commissioner of health, not less than thirty-five per cent for equipment and not less than fifty-five per cent for methods.

Such milk and cream must be delivered within thirty-six hours of the time of milking.

Such milk and cream must be delivered to consumers only in containers filled at the dairy or central bottling plant.

The caps must contain the word "Certified" and bear the certification of a milk commission appointed by the county medical society organized under and chartered by the medical society of the state of New York, and must also contain the name and address of the dairy as well as the date of milking.

Every employee before entering upon the performance of his duties shall be examined by a duly licensed physician and the reports of such examination shall be sent to the milk commission certifying the milk from such dairy.

The milkers and all persons handling the milk must be provided with suits and caps of washable material which shall be worn while milking or handling the milk and shall not be worn at other times. When not in use these garments must be kept in a clean place free from dust. Not less than two clean suits and caps must be furnished weekly. The hands of the milkers must be washed with soap and hot water, and well dried with a clean towel, before milking.

Grade A raw. No milk or cream shall be sold or offered for sale as "Grade A raw" unless it conforms to the following requirements:

The dealer selling or delivering such milk or cream must hold a permit from the local health officer.

All cows producing such milk or cream must have been tested at least once during the previous year with tuberculin, and any cow reacting thereto must have been promptly excluded from the herd.

Such milk must not at any time previous to delivery to the consumer contain more than 60,000 bacteria per cubic centimeter, and such cream not more than 300,000 bacteria per cubic centimeter.

Such milk and cream must be produced on farms which are duly scored on the scorecard prescribed by the state commissioner of health not less than twenty-five per cent for equipment, and not less than fifty per cent for methods.

Such milk and cream must be delivered within thirty-six hours from the time of milking, unless a shorter time shall be prescribed by the local health authorities.

Such milk and cream must be delivered to consumers only in containers sealed at the dairy or a bottling plant. The caps or tags must be white and contain the term "Grade A raw" in large black type, and the name and address of the dealer.

Grade A pasteurized. No milk or cream shall be sold or offered for sale as "Grade A pasteurized" unless it conforms to the following requirements:

The dealers selling or delivering such milk or cream must hold a permit from the local health officer.

All cows producing such milk or cream must be healthy as disclosed by an annual physical examination.

Such milk or cream before pasteurization must not contain more than 200,000 bacteria per cubic centimeter.

Such milk must not at any time after pasteurization and previous to delivery to the consumer contain more than 30,000 bacteria per cubic centimeter, and such cream not more than 150,000 bacteria per cubic centimeter.

Such milk and cream must be produced on farms which are duly scored on the scorecard prescribed by the state commissioner of health not less than twenty-five per cent for equipment and not less than forty-three per cent for methods.

Such milk and cream must be delivered within thirty-six hours after pasteurization, unless a shorter time shall be prescribed by the local health authorities.

Such milk and cream must be delivered to consumers only in containers sealed at the dairy or at a bottling plant. The caps or tags must be white and contain the term "Grade A pasteurized" in large black type.

Grade B raw. No milk or cream shall be sold or offered for sale as "Grade B raw" unless it conforms to the following requirements:

The dealer selling or delivering such milk or cream must hold a permit from the local health officer.

All cows producing such milk or cream must be healthy as disclosed by an annual physical examination.

Such milk must not at any time previous to delivery to the consumer contain more than 200,000 bacteria per cubic centimeter, and such cream not more than 750,000 bacteria per cubic centimeter.

Such milk and cream must be produced on farms which are duly scored on the scorecard prescribed by the state commissioner of health not less than twenty-three per cent for equipment and not less than thirty-seven per cent for methods.

Such milk and cream must be delivered within thirty-six hours from the time of milking, unless a shorter time shall be prescribed by the local health authorities.

The caps or tags on the containers must be white and contain the term "Grade B raw" in large, bright green type, and the name of the dealer.

Grade B pasteurized. No milk or cream shall be sold or offered for sale as "Grade B pasteurized" unless it conforms to the following requirements:

The dealer selling or delivering such milk or cream must hold a permit from the local health officer.

All cows producing such milk or cream must be healthy as disclosed by an annual physical examination.

Such milk or cream before pasteurization must not contain more than 1,500,000 bacteria per cubic centimeter.

Such milk must not at any time after pasteurization and previous to delivery to the consumer contain more than 100,000 bacteria per cubic

centimeter, and such cream not more than 500,000 bacteria per cubic centimeter.

Such milk and cream must be produced on farms which are duly scored on the scorecard prescribed by the state commissioner of health not less than twenty per cent for equipment and not less than thirty-five per cent for methods.

Such milk must be delivered within thirty-six hours after pasteurization between April first and November first and within forty-eight hours after pasteurization between November first and April first, and such cream within forty-eight hours after pasteurization, unless a shorter time is prescribed by the local health authorities.

The caps or tags on the containers must be white and contain the term "Grade B pasteurized" in large, bright green type, and the name of the dealer. (Amended Mar. 4, 1915, Oct. 5, 1915, Jan. 9, 1917 and Jan. 10, 1919.)

Grade C raw. No milk or cream shall be sold or offered for sale as "Grade C raw" unless it conforms to the following requirements:

The dealer selling or delivering such milk or cream must hold a permit from the local health officer.

Such milk and cream must be produced on farms which are duly scored on the scorecard prescribed by the state commissioner of health not less than forty per cent.

Such milk and cream must be delivered within forty-eight hours from the time of milking, unless a shorter time shall be prescribed by the local health authorities.

The caps or tags affixed to the containers must be white and contain the term "Grade C raw" in large red type.

Grade C pasteurized. No milk or cream shall be sold or offered for sale as "Grade C pasteurized" unless it conforms to the following requirements:

The dealer selling or delivering such milk or cream must hold a permit from the local health officer.

Such milk and cream must be produced on farms which are duly scored on the scorecard prescribed by the state commissioner of health not less than forty per cent.

Such milk and cream must be delivered within forty-eight hours after pasteurization, unless a shorter time shall be prescribed by the local health authorities.

The caps or tags affixed to the containers must be white and contain the term "Grade C pasteurized" in large red type.

All tuberculin tests and physical examinations of cows herein provided for shall be made by a licensed veterinarian approved by the state department of agriculture.

The bacterial count herein required shall be made only at county or municipal laboratories or such other laboratories as may be approved by the state commissioner of health.

In those municipalities where a bacterial count of the milk is, in the opinion of the local health authorities, impracticable, they may in their

discretion grade milk and cream according to the score of the dairies producing it, as prescribed in this regulation, but no such milk shall be designated "certified," "Grade A raw," or "Grade A pasteurized."

This regulation shall not be construed to rescind or modify any existing local regulation or ordinance controlling the grading of milk or cream established prior to the first day of September, 1914. (Amended Mar. 4, 1915, Oct. 5, 1915, Jan. 9, 1917, Mar. 1, 1918, Jan. 10, 1919 and Nov. 18, 1919.)

Regulation 14. Supplementary regulations by local authorities. The health authorities of any municipality may in their discretion increase the stringency of these regulations or add to them in any way not inconsistent with the provisions thereof, and may prohibit the sale, or the keeping for sale, within the municipality of any of the grades of milk herein defined. Any city of the first class may provide for additional grades of milk and cream subject to the approval of the public health council. (Amended July 10, 1917 and April 20, 1922.)

Regulation 14-a. Milk or cream in cold storage warehouses. Nothing contained in this chapter in reference to the time of delivery of milk and cream shall be deemed to prohibit the keeping of such milk and cream in cold storage in a duly licensed cold storage warehouse for a period of not more than twelve calendar months; provided, such milk and cream is placed in such cold storage warehouse within forty-eight hours after milking or pasteurization, as the case may be. (Added Mar. 1, 1918 and amended June 10, 1921.)

Regulation 15. When to take effect. Every regulation in this chapter unless otherwise specifically stated shall take effect throughout the state of New York except the city of New York on the sixteenth day of November, 1914.

SOUR MILK DRINKS

For a number of years there has been an increased demand on the part of the public for sour milk drinks. This demand was so great that for a time some of the larger milk companies manufactured their own brand of buttermilk and these sour milk beverages were sold at soda fountains, restaurants and drug stores. Zoolak, Matzoon, Bulgarian buttermilk, Kefir, Kumia and Yogart were some of the names given to these sour milk drinks and there were many others besides these mentioned.

The demand for these sour milk drinks is due to their benefit in correcting digestional disorders, and there are two theories in regard to the manner in which benefit is derived from them.

The first theory is that the human system becomes poisoned by putrefaction taking place in the intestines and this decomposition is due to putrefactive bacteria which split up the proteins. The abnormal condition resulting from this protein decomposition is referred to as autointoxication. By drinking sour milk, of one kind or

another, lactic acid types of bacteria are introduced into the digestive tract and if this diet of sour milk is continued, the bacteria in the milk gradually supplant the putrefactive types and become the predominating flora of the intestinal tract. Some investigators claim that if sour, or fermented milk, as it is often called, is taken for a considerable time and then its use in the diet is discontinued, the acid-producing organisms will persist for a long time in the digestive tract, as shown by their presence in the feces. Others claim that this is not the case, and as soon as the use of sour milk in the diet is discontinued the lactic acid types of bacteria disappear from the intestinal tract.

The second theory in regard to the beneficial effects of sour milk in the diet is the value of lactic acid. The value of lactic acid as a food preservative is well known in pickling—as in making cucumber pickles and in making sauerkraut. The presence of comparatively large quantities of lactic acid prevents the splitting up of proteid substances into poisonous products. The acid also is supposed to act as a stimulant to the various digestive agencies and in this way foods taken into the stomach are more completely digested.

The interest in the use of sour milk drinks in the diet was greatly stimulated by Metchnikoff's book, entitled "The Prolongation of Life." In this book the author stated that in certain countries where sour milk drinks are the main article of diet, the inhabitants live to a great age, and are very robust in health and that this condition of affairs is due to the diet of sour or fermented milk. Metchnikoff lays great stress on the value of lactic acid in preventing intestinal putrefaction.

Some investigators believe that whatever may be the value of sour milk in preventing autointoxication, the deductions of Metchnikoff are not supported by actual facts.

Rogers [77] cites experimental work in which equally good results were obtained by feeding chicks sweet and sour milk, and there seemed to be no difference between milk soured by the common lactic acid types and that soured by bacillus bulgaricus. When milk in the diet of white rats was replaced by milk sugar, so far as its effect on the intestinal flora was concerned, the sugar had the same effect as the milk. Rogers concludes that this experimental evidence

[77] Rogers, L. A., Fermented Milks, U. S. Dept. of Agr. Bull. No. 319.

proves that one of the chief values of milk in controlling intestinal flora is to furnish milk sugar which stimulates the growth of high acid-producing organisms whose habitat is in the intestines. The stimulation of the growth of these organisms takes place to such an extent that the putrefactive types are replaced by the acid-producing types.

In connection with the question of the benefit of sour milk drinks, the food value of these beverages should not be lost sight of. The question of the food value of milk has already been discussed and need not be repeated. It should be borne in mind, however, that drinking regularly a definite amount of sour milk not only furnishes lactic acid, the proper flora for the intestinal tract, and the correct food for acid producing bacteria, but it also furnishes for the body, protein in a very available form and also soluble mineral matter. It seems only reasonable that the high food value of these sour milk beverages would play an important part in the benefit derived from their use.

Sour and fermented milk beverages are prepared by three main groups of organisms: (1) the lactic acid type such as is commonly used for souring milk in different dairy operations, as in souring cream for buttermaking; (2) the bacillus bulgaricus type; and (3) yeasts. In some of the prepared sour milk drinks, other organisms have been found but their value in connection with the preparation of the sour milk drink is very much in doubt, and they are usually regarded as a contamination.

There are a great many different kinds of the so-called lactic acid types of organisms. Many of these have been studied and classified, among which are bacterium lactis acidi, streptococcus lacticus, and bact. guntheri. These are probably all the same organism. They are about 0.5 to 1 microns in length and there is considerable dispute as to whether they should be classified as short rods or as cocci. Later authorities are inclined to classify them as streptococci as they are commonly found in chains of two organisms and sometimes in chains of four organisms. They readily produce acid in milk up to about 0.7 per cent to 1 per cent although the latter amount is not generally reached. This organism will grow well at 37° C. (98.6° F.), but will also grow at 21.1° C. (70° F.) This latter temperature is not generally favorable for most putre-

factive organisms, which usually require a high temperature for growth and for this reason the lactic acid organism is usually propagated at a temperature from 21.1° C. (70° F.) to 23.8° C. (75° F.)

The bulgaricus type of organism is a long, slender rod sometimes attaining a length of 8 to 10 microns. It will produce large amounts of acid, sometimes as high as 2 per cent. It grows best at high temperatures, around 37.7° C. (100° F.) and on account of its rapid growth and the large amounts of acid which it produces, it tends to suppress putrefactive forms. Bacillus bulgaricus takes its name from Bulgarian buttermilk, from which it was isolated by Metchnikoff.

In making sour milk drinks, it is nearly always advisable to pasteurize the milk from which they are made. This process kills off most of the organisms which may be in the milk and allows those which may be added in preparing the sour milk drink to grow without opposition from other microörganisms. Some are also of the opinion that pasteurization improves the body of the final product, but care should be taken not to heat the milk to such a temperature and for such a length of time that the albumin will be precipitated. Only milk of the very best sanitary quality should be used in making sour milk drinks. If milk is highly contaminated, the process of pasteurization may destroy the organisms, but it will not necessarily remove the flavors which may be present as a result of this action and these may develop later and injure the quality of the final product.

BUTTERMILK

One of the most common and well known of the sour milk drinks is buttermilk. This was originally the milk which was left after churning sour cream, which had been ripened with lactic acid bacteria. In many sections of the country very little churning is carried on and in order to supply the demand buttermilk is made artificially from ordinary skimmilk, soured with a culture of lactic acid organisms. So far as its composition is concerned, the soured skimmilk is much the same as that of genuine buttermilk with the exception of the fat content. Buttermilk usually has a higher fat content than the soured skimmilk, the fat content of the former often going as high as 0.5 per cent. Buttermilk, suitable for purposes as

a beverage, should have a smooth texture, often described as creamy, be free from lumps, and be of a clean acid flavor with no foreign odors or flavors.

The skimmilk when made into artificial buttermilk is soured with a special culture of lactic acid organisms. These cultures are obtained of the different dairy supply houses in powder, or semi-fluid or fluid condition, and very frequently contain other than lactic acid organisms. For this reason the culture must be purified until it contains practically no organisms other than those desired. In order to make this pure culture a pint or quart of sweet skimmilk is pasteurized at a temperature of 150° F. for 30 minutes. This is then cooled to a temperature of 70°-72° F. and some of the culture either in the powder, fluid or semi-fluid form is added and the mixture shaken. This mixture is then held at 70°-72° F. until the contents of the bottle curdles. Another pint or quart of milk is pasteurized and cooled to 70°-72° F. and some of the previous culture is added to it and this is held at the above mentioned temperatures until it thickens. Ten to 12 hours will usually be required for the culture to thicken, although the time required will vary with different cultures. The method of making a new culture each day as described above is repeated until a culture is obtained which has a clean sharp acid taste and odor and in which the curd is smooth and free from gas bubbles. This culture may then be used to inoculate a larger amount of pasteurized skim milk.

One of the difficulties encountered in making artificial buttermilk is the tendency for the watery portion and the solid portion of the skimmilk to separate, or, as the dairyman terms it, the buttermilk "wheys off." This trouble increases as the product gets older and the percentage of acid increases, and a sure method of preventing this trouble in all cases has never been found. This trouble can be partly remedied and in some instances obviated entirely by churning the soured skimmilk the same as genuine buttermilk is churned. This process separates the particles of casein so fine that they will stay in suspension much better than they otherwise would do.

Some manufacturers make the mistake of allowing the product to become too sour before placing it on the market. Unfortunately the customer sometimes has the opinion that because the product is sour it does not have to be cared for the same as ordinary milk

and the buttermilk is allowed to warm up to such a temperature that the acidity increases very rapidly. This may cause the buttermilk to whey off and the product to become so highly acid that the customer does not like it. By allowing the product to become highly acid the manufacturer, in most cases, anticipates changes which will take place fairly readily after the milk has been delivered to the customer. This is all the more true since much of the demand for buttermilk, to be used as a beverage, is in the summer months when the temperature is favorable for raising the temperature of the buttermilk.

After a culture of buttermilk has been carried for some time it is quite likely to lose its vitality. This will be apparent in slowness of growth, lack of the characteristic lactic acid flavor and odor, and sometimes by actual putrefactive changes in the milk. In such cases a new culture should be started and care should be taken that this is done in plenty of time before the old culture becomes useless.

By using various bacteriological methods old cultures can frequently be revivified, but these methods usually require special media and considerable laboratory technique, and usually the manufacturer might better start a new culture as suggested above.

YAHOURTH, YOGURT, BULGARIAN BUTTERMILK

Probably one of the most convenient ways of starting a culture of Bulgarian buttermilk is to do so from tablets which may be purchased from almost any drug store. As has been pointed out, the main alleged value of Bulgarian buttermilk is to start a flora of bacillus bulgaricus in the intestines and thus suppress putrefactive types of organisms. To some people milk of any kind is very unpalatable, and in order to accommodate such individuals and also on account of convenience, the bulgaricus organism is furnished in tablet form. Care should be taken, however, in using the tablets for any purpose, to make sure they are fresh, as they will not long remain viable in a dry medium. The container of the tablets has printed on it a date after which the viability of the tablets is not guaranteed, and this date should always be observed before making use of them.

In making Bulgarian buttermilk a pint or quart of skimmilk should be pasteurized at a temperature of 150° F. (65.5° C.) for

30 minutes and then cooled to around 100° F. (about 37.7° C.) and two or three of the Bulgarian buttermilk tablets added to it, and the mixture shaken until the tablets are dissolved. The milk should be held at the above-mentioned temperature until it curdles, which will usually take place in 8 to 12 hours. In order to get a good product several transfers are usually necessary, the same as in making ordinary artificial buttermilk. Each new pint or quart of pasteurized skimmilk is inoculated with some of the culture made the previous day and after four or five transfers a good sample of Bulgarian buttermilk should be obtained, having a thick creamy consistency and a very sharp lactic acid flavor and odor, free from gas and taint of any kind. This culture may be carried for a long time by adding some of the previous day's culture to new lots of pasteurized skimmilk, but if for any reason the cultures become lacking in vitality, it is best to start a new culture from the tablets, or from an active culture obtained from a laboratory.

After the Bulgarian buttermilk has curdled it is best to cool it so that the acid will not develop to such an extent that it will attack the casein.

Frequently, a sour milk drink is made by growing together the lactic acid organism such as bact. lactis acidi and B. bulgaricus. Such a culture produces a product which is pleasing to many people in that it has a higher acid flavor than is produced in ordinary buttermilk, and at the same time has not the extremely high acid taste which is characteristic of Bulgarian buttermilk.

Perhaps it should be mentioned here that the likes or dislikes of consumers of buttermilk are quite apt to be a matter of education. If they are used to a mild acid flavor, Bulgarian buttermilk with its extremely high acidity will be distasteful. However, after becoming accustomed to the high acidity, people usually like it.

ACIDOPHILUS BUTTERMILK

A sour milk drink similar to Bulgarian buttermilk is made by using B. acidophilus. This is a large organism, morphologically similar to B. bulgaricus, and, like that organism, it produces large amounts of lactic acid. The advantage which is claimed for B. acidophilus over B. bulgaricus is that the former organism is always found in the intestinal tract of healthy infants, and if not present

it will find a permanent habitat in the intestines of man more readily than will B. bulgaricus.

In the manufacture of buttermilk with acidophilus, it is necessary to have the milk sterile before inoculation. Acidophilus starts growth very slowly and if other organisms are present they will overcome the acidophilus and cause the product to spoil. The slow growth of B. acidophilus is in direct distinction to B. bulgaricus, which starts growth very rapidly and which therefore more readily overcomes any organisms which may be present.

KEFIR

Kefir is a sour milk drink differing from most other milk beverages, in that it contains alcohol, as well as lactic acid. This drink has for centuries been one of the main articles of diet of some of the inhabitants of Russia and the Balkan states and some portions of Turkey.

A culture of Kefir is made from a previous culture from which are taken for the purpose so-called "grains" or "seeds." When these are added to fresh milk, new ones form, thus increasing the size of the mass of grains or seeds. To describe this mass is difficult but they have been described as similar in appearance to pieces cut from the head of cauliflower.

These grains may be strained from the Kefir and dried and in this dry condition are said to remain viable for a long time.

The biology of the Kefir grains is not definitely known. Freudenreich [78] seems to have done the most work on this fermented milk drink, although his results do not agree with the work of some other investigators. He found four organisms which were thought to be necessary in the manufacture of Kefir. One of these was a long rod, similar to B. bulgaricus, which he named B. caucasius. Two of the organisms were of the ordinary lactic acid type and the fourth was a yeast. All of the organisms seemed to be necessary to produce typical Kefir.

In countries where Kefir is a regular article of diet, it is made by placing milk in leather bags and adding to the milk some material from a culture of Kefir or some dried Kefir grains. The bags are hung in the sun and shaken frequently. The milk soon turns

[78] Freudenreich, Edw., Annales of Murographe, Vol. 9.

sour and alcohol and gas also form. The presence of gas is considered a desirable characteristic of a good sample of Kefir.

A fermented milk drink closely resembling Kefir may be made by adding yeast, cane sugar and acid producing bacteria to a sample of skimmilk and holding the mixture at a temperature of about 70° F. (about 21° C.). According to Rogers (*loc. cit.*) the amount of alcohol and gas formed is dependent on the amount of sugar added.

KUMISS (KUMYSS)

Kumiss is a regular article of diet of certain wandering tribes in Russia and southwestern Asia. These tribes are great lovers of horses and have developed a strain of mares that give unusually large quantities of milk, which constitutes the chief food of these natives. The milk is not eaten in its natural raw state, but is made into Kumiss, which contains lactic acid and a small amount of alcohol. The Kumiss was made by placing the milk in leather bags and adding a small amount of an old culture of Kumiss to the fresh milk. If no old culture was at hand, fermentation was started by adding a piece of decaying flesh or vegetable matter. It is also stated that a copper coin covered with verdigris was sometimes used to start fermentation. It can readily be seen that Kumiss might have a varying flora depending on the circumstances under which it was made.

The natives who subsisted on Kumiss seemed to be so healthy that the use of Kumiss became at one time very popular and "Kumiss cures" were started at one time in Moscow and St. Petersburg (Petrograd). Enough mare's milk could not be obtained to supply the demand created by these Kumiss cures and so the beverage was made from cow's milk.

According to Jenkins [79] it is more difficult to manufacture Kumiss from cow's milk than it is from mare's milk because the milk from the cow forms such a firm, hard coagulum that it is more difficult to set up fermentation. The same authority states that a Dr. Viedth of London was the first man to make Kumiss of a definite composition from cow's milk.

In a study of the bacterial flora of Kumiss, Jenkins found almost

[79] Jenkins, Minnie, The Flora of Fermented Milk Drinks, Thesis, Cornell University, 1909.

a pure culture of an organism of the bacterium lactis acidi type and a yeast similar to the one used in bread making. It will be noted that the method previously mentioned for making artificial Kefir with some acid organism, yeast and sugar, might produce a product very similar to Kumiss. The similarity of the two products would probably depend largely on the amount of sugar used, as this would control the fermentation of alcohol.

In making any kind of sour or fermented milk drink, too much stress cannot be placed upon the necessity of preventing contamination. While the necessary steps involved are comparatively simple, yet the process is a bacteriological one and inattention to details, such as unsterile utensils, exposure to dust or dirt, or carelessness in regard to temperature of propagation, will result in a poor product.

Chapter X

THE PRODUCTION OF CLEAN MILK

The purpose of this chapter is to collect in one group some of the practises which are of benefit in producing milk of good sanitary quality. Some important points are mentioned elsewhere in this book and will, therefore, only be touched upon here, but certain other practises which are important deserve special consideration.

The production of clean milk is neither difficult nor expensive. Unfortunately the idea is prevalent among dairymen that the production of a good grade of market milk requires an outlay of a large amount of money. This is not the case, for many dairymen are producing a good grade of market milk with what would be rated as poor equipment and on the other hand dairymen who have invested large amounts of money are producing milk of poor sanitary quality. These statements do not necessarily mean that because a dairyman is producing milk he is making money. In fact, some dairymen may be actually losing money, but if a man is engaged in milk production it will, in most cases, cost him no more and in any case very little more, to produce clean milk over what it would cost to produce dirty milk.

A certain well-known educator has said that in order to produce clean milk a person must have a clean mind, and this statement means that a successful dairyman must know what constitutes cleanliness. With many people, the term cleanliness has only a relative meaning. In order to produce clean milk a person, in addition to knowing what constitutes cleanliness, must be willing to pay attention to the details which are necessary in clean milk production. If a dairyman is not willing to watch these details, he will never be successful so far as the production of clean milk is concerned.

Table 46.—A Comparison of the Bacteria Count in Milk as Obtained by Two Different Milkers Under the Same Conditions.

Experiment Number	Milker Number	Total Bacteria per c.c.
No. 1	No. 1	2463
	No. 2	2756
No. 2	No. 1	2050
	No. 2	4467
No. 3	No. 1	1654
	No. 2	2575
No. 4	No. 1	1258
	No. 2	5600
No. 5	No. 1	907
	No. 2	2690
No. 6	No. 1	1606
	No. 2	10050
No. 7	No. 1	142
	No. 2	12617
No. 8	No. 1	731
	No. 2	180350
No. 9	No. 1	1452
	No. 2	13700
No. 10	No. 1	4933
	No. 2	13604
No. 11	No. 1	2650
	No. 2	2104
No. 12	No. 1	2917
	No. 2	4938
No. 13	No. 1	1866
	No. 2	5688
No. 14	No. 1	4133
	No. 2	17583
No. 15	No. 1	950
	No. 2	4104
No. 16	No. 1	4417
	No. 2	6813
No. 17	No. 1	2383
	No. 2	2854
No. 18	No. 1	7217
	No. 2	24938
No. 19	No. 1	2917
	No. 2	7583
Average	No. 1	2455
"	No. 2	17105
Difference in favor of No. 1	.....	14650

THE PERSONAL ELEMENT

The difference in individuals in producing clean milk is well illustrated in the above table.[80] In this experiment all of the

[80] Stocking, W. A., Jr., Storrs Agr. Exp. Sta. Bull. No. 42.

conditions surrounding the operation of milking were as nearly alike as possible in both cases. The difference in bacteria count obtained by the two milkers is, therefore, largely due to the difference in the care exercised by the two men.

HEALTHY ANIMALS

The first prerequisite in producing clean milk is to have healthy animals. This question has been studied and emphasized from the standpoint of tuberculosis but there are many other diseases common to cattle which should not be overlooked. It must be admitted that in many cases the transmission of bovine diseases to humans cannot be proven, but experimental medicine has proven that many diseases may be transmitted at certain times to certain people, and at other times and to other people it will not be transmitted. Take, for example, the case of garget in milk. So far as we know it has never been actually proven that garget in milk will produce a disease in human beings. However, garget in milk is due to an abnormal, and in some cases is accompanied by a feverish condition of the udder. If this milk is fed to infants, it may cause intestinal disturbances and the infant will become ill although it could not properly be said to have contracted a specific disease.

It is sometimes difficult to tell just why one person will, under certain circumstances, produce milk of low germ content, and another person, under identically the same circumstances, produce milk of high germ content. Sometimes, however, the difference is due to some act on the part of the milker and a good example of this kind is milking with wet hands. Some people are of the opinion that wetting the hands with milk makes the process easier. When this is done, the milk drips from the hands into the pail, carrying with it any microörganisms which may be on the hands of the milker or the teats of the cow. The number and kinds of bacteria introduced into the milk in this way would vary, but under some circumstances the numbers might be large and it would be easily possible to introduce pathogenic organisms into milk by this method. The practise of milking with wet hands is abominable, and is never tolerated in dairies producing clean milk.

The infection of milk with pathogenic organisms from the person of the milker has been fully discussed in another chapter. It will

do no harm, however, to repeat here that milkers have a big responsibility in this matter. Certified milk dairies usually require their employees to submit to a physical examination once a month, and this same practise is followed by many others producing high grade milk.

In many cases it is puzzling to know whether or not certain diseases will affect the purity of the milk supply. If, for example, a cow should break one of its legs and was considered valuable enough to keep until she recovered, the question would at once arise as to the advisability of using the milk during the period of recovery. It would be almost impossible to tell under such circumstances whether or not the milk was fit for human consumption and the safest course to follow is to withhold the milk from the regular supply until all feverish conditions have disappeared. If an animal, which to all appearances has been giving normal milk, suddenly shows symptoms of being abnormal, such as loss of appetite or shrinkage of the milk supply, such an animal should be removed from the herd, until the nature of the disease is determined or until such time as the animal recovers. Such symptoms may be caused by indigestion from which the animal will recover within a short time. They may, however, be the forerunner of some of our worst bovine diseases.

One of the most common causes of abnormal milk is injury to the udder. In such cases very frequently only one quarter of the udder is affected and it is next to impossible to determine whether the entire supply is affected. So far as can be determined by all known tests the milk from the sound three-quarters will very frequently appear perfectly normal. In such cases it is safest to keep from the regular milk supply the milk from the injured quarter until such time as all feverish conditions have disappeared.

Another condition difficult to judge is when the colostrum stage of milk has passed. Some people are of the opinion that colostrum milk is never harmful, but that the only difference between colostrum milk and normal milk is a difference in composition. While it is true that colostrum differs chemically from normal milk, it is also true that it may contain products due to a feverish condition of the udder, which will render the milk decidedly unsafe for human consumption. In New York State the dairy law forbids the sale of

milk for market purposes either within 15 days before or five days after parturition. While this time limit would cover the majority of cases, it would not cover them all. The milk from some animals is to all appearances perfectly normal within two days after parturition, while with others the colostrum stage will persist for many days. In actual practise of milk production, the milk consumer must rely on the judgment and honesty of the producer to withhold from the market the milk from animals which have freshened until such time as the milk has become normal. If the producer realizes his responsibility in this matter and is honest, very little abnormal milk will find its way into the market.

CLEAN ANIMALS

The condition of the cow, whether she is clean or dirty, is important in producing clean milk. If bits of manure, shavings, straw or hair are clinging to the udder and flanks of the cow, they may very easily fall into the milk pail. Some milk companies require that the udder and flanks of the cow be clipped at least twice a year. This tends to remove loose hairs, makes it easier to keep the cow clean, and also makes it less easy for dirt of various kinds to cling to the body of the animal and thus find its way into the milk pail and cause a comparatively large bacteria count in the milk. This is well illustrated in the following table,[81] which is the result of an experiment performed by the Dairy Division of the U. S. Department of Agriculture.

Table 47.—Comparatively Large Number of Bacteria in Milk Due to Dirty Methods of Production.

Sample No.	Bact. per c.c	Sample No.	Bact. per c.c
1	45,000	9	200,000
2	60,000	10	340,000
3	150,000	11	750,000
4	450,000	12	350,000
5	200,000	13	750,000
6	130,000	14	400,000
7	160,000	15	600,000
8	175,000		

[81] Ayres, S. Henry, Cook, Lee B., and Clemerer, Paul W., The Four Essential Factors in the Production of Milk of Low Bacterial Content, U. S. Dept. of Agr. Bull. No. 642.

In the experiment from which the figures in the above table were gathered the conditions were allowed to become extremely unsanitary. The manure was removed only once per week and the bodies of the cows were covered with dried manure. It will be noted that for the first two or three days the bacteria count was not excessively high, but as the filth accumulated, the bacteria count increased. While some of the counts may not at first seem excessively high, it must be remembered that the milk was fresh and that the count represents initial contamination. All of the samples were drawn in a small top milk pail.

Table 48.—Decrease in Bacteria in Milk Due to Wiping the Udder of the Cow with a Damp Cloth Just Before Milking.

Experiment	Treatment of Cows	Total Bacteria per c.c.
No. 1	Not wiped	1070
	Wiped	1030
No. 2	Not wiped	2780
	Wiped	530
No. 3	Not wiped	64590
	Wiped	250
No. 4	Not wiped	490
	Wiped	800
No. 5	Not wiped	725
	Wiped	575
No. 6	Not wiped	1310
	Wiped	310
No. 7	Not wiped	505
	Wiped	325
No. 8	Not wiped	800
	Wiped	754
No. 9	Not wiped	210
	Wiped	100
No. 10	Not wiped	660
	Wiped	385
No. 11	Not wiped	15475
	Wiped	3025
No. 12	Not wiped	1130
	Wiped	590
No. 13	Not wiped	2010
	Wiped	650
Average	Not wiped	7058
	Wiped	716
Decrease due to wiping		6342

MOISTENING UDDER AND FLANKS

Washing the udder and flanks of the cow just before milking will, as is to be expected, greatly reduce the germ content of the freshly drawn milk and this practise is followed in certified milk dairies. It has been found, however, that simply moistening the flanks and the udder of the cow with a damp cloth will greatly aid in producing milk of low bacteria content. This practise is easily and rapidly carried out, is inexpensive, and is, therefore, applicable to the ordinary dairy farm. The value of this practise in clean milk production is shown in Table 48 taken from Connecticut (Storrs) Bulletin No. 42 (*loc. cit.*).

CLEAN, STERILE UTENSILS

One of the greatest sources of bacteria in milk is the milk utensils. In cases where trouble is experienced with milk containing a large number of bacteria an investigation will often show that the pails, cans, or other apparatus contain a yellow, slimy deposit which

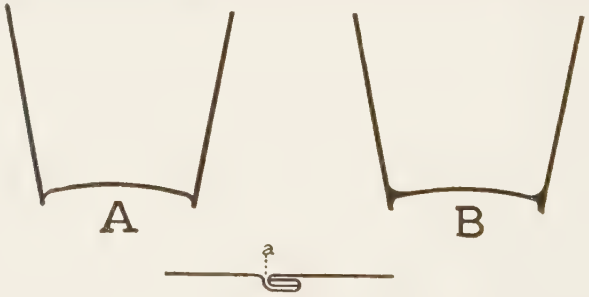

FIG. 10. The Right and the Wrong Kind of a Milk-Pail. A, the Ordinary Type of Pail Showing Sharp Angle Between Sides and Bottom; B, the Same Properly Flushed with Solder so as to Facilitate Thorough Cleaning. The Lower Figure Represents a Joint as Ordinarily Made in Tinware. The Depression A Affords a Place of Refuge for Bacteria from Which They Are Not Readily Dislodged. This Open Joint Should be Filled Completely With Solder.

is loaded with bacteria. All dairy utensils, no matter what their purpose, should be constructed of good material and they should be free from cracks and crevices where dirt and dried milk can collect. All seams should be well flushed with solder. To clean properly a

dairy utensil it should be rinsed first in cold or lukewarm water. If hot water is used, it will cook the albumin of the milk onto the apparatus and this is very difficult to remove. The utensil should then be washed with warm water to which has been added some washing powder and then the utensil should be rinsed in hot water and scalded with boiling water or better still exposed to the action of live steam for not less than half an hour. The purpose of scalding or steaming is to render the utensil as near sterile as possible, but whichever method is used, it is very important that the utensil be dried at once and kept dry until used. In cleaning and rendering milk utensils as near sterile as possible there are usually left alive a few bacteria and in a utensil which contains even a small amount of water, bacteria find a most favorable medium in which to grow and multiply. This is well illustrated in the following table.[82]

Table 49.—Increase of Bacteria in Cans Which Were Washed, Not Dried and Held 24 Hours.

Series No.	Bacteria per Can	
	Freshly Washed	24 Hours After Washing
1	960,000	847,000,000
2	618,000	2,612,000,000
3	137,000	336,000,000
4	91,000	428,000,000
5	99,000	320,000,000
6	5,570,000	748,000,000
7	305,000	138,000,000
Average	1,111,514	775,751,429

The effect of drying dairy utensils upon the multiplication of germ life is well illustrated by the following data: [83] 50 cans, washed, steamed, inverted on a rack for 30 hours, would have contributed 8 bacteria per c.c. if cans had been filled with milk.

50 cans washed, steamed, but left 30 hours with lids on would have contributed 1,816 bacteria per c.c. if cans had been filled with milk.

50 cans washed but not steamed, inverted on a rack for 30 hours would have added 27,164 germs per c.c. if cans had been filled with milk.

[82] Milk Inspector Letter No. 64. Bureau of Dairying, U. S. Dept. of Agr.

[83] Prucha, M. J., Weter, H. M., and Chambers, W. H., The Germ Content of Milk as Influenced by Utensils, Uni. of Ill. Bull. No. 204.

10 cans washed but not steamed, held for 30 hours with lids on would have added 128,730 bacteria per c.c. if cans had been filled with milk.

From this data it can be seen that under any method of treatment drying utensils after washing them has a big influence in preventing bacterial growth.

The above data also illustrates the value of steam sterilization in regard to clean milk production.

FIG. 11. Small Sterilizer Made of Galvanized Iron, Suitable for Use Where Steam is Available.

The value of sterilizing dairy utensils in clean milk production is clearly shown in Table 50.[84] In this experiment the milk was produced under unsanitary conditions. The milk was poured from the pail into a can and the sample taken from the can. In one case the utensils were sterilized and in the other case they were not sterilized and the figures here given are from milk drawn in a small top pail.

It should also be explained that the comparisons of the sterilized and unsterilized utensils were not made on the same day. How-

[84] Clemerer, Bull. 642, U. S Dept. of Agr. (*loc. cit.*).

ever, the barn conditions were kept so nearly uniform that this fact would have no practical effect in proving or disproving the value of sterilizing dairy utensils in clean milk production.

Table 50.—Effect of Sterilization of Dairy Utensils upon Clean Milk Production.

Sample Number	Bacteria per c.c. in Milk When Utensils Were Sterilized	Not Sterilized
1	9,000	45,000
2	20,000	60,000
3	11,000	150,000
4	16,000	450,000
5	2,500	200,000
6	23,000	130,000
7	2,400	160,000
8	45,000	175,000
9	35,000	200,000
10	32,000	340,000
11	240,000	750,000
12	2,500	350,000
13	3,800	750,000
14	2,600	400,000
15	12,500	600,000
16	2,800	550,000

If steam is not available for purposes of sterilization, boiling water may be used very effectively. One trouble with boiling water is the fact that it takes quite a large volume to do the work efficiently and when the hot water is poured from one utensil to another it soon becomes cooled to a point where it will not kill germ life. This drop in temperature is illustrated in the following table.[85]

Table 51.—Drop in Temperature of Rinsing Water When Poured from One Can to Another.

Amount of Water Quarts	Temperature of Rinsing Water Before Rinsing ° F.	After 1st Can ° F.	After 2nd Can ° F.	After 3rd Can ° F.	After 4th Can ° F.	Total Drop in Temperature ° F.
2	210	158	131	113	100	110
6	210	178	160	150	138	72

Two things are shown very clearly by the above table. In the first place scalding water cools very rapidly when poured from one milk can to another and soon reaches a temperature so low that it

[85] Prucha, M. J., and Harding, H. A., Elimination of Germs from Dairy Utensils, Ill. Agr. Exp. Sta., Bull. No. 230.

would have very little effect on germ life. In the second place the volume of scalding water used has a big influence on the rapidity of a drop in temperature.

While steam is the most effective method of sterilizing dairy utensils, it very frequently happens that they are not exposed long enough and not enough volume of steam is used to raise the utensils to the proper temperature. The volume of steam delivered by a

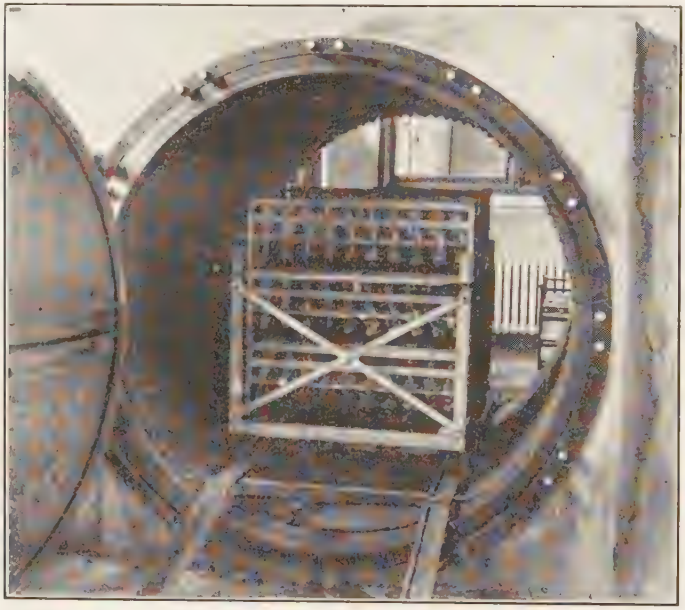

FIG. 12. High Pressure Sterilizer. This Type of Sterilizer is Sometimes Used in Certified Milk Production.

boiler within a given time depends on the number of pounds pressure carried on the boiler. This is well shown in Table 52.[86]

Another important feature in the efficiency of the steam sterilizer is its construction with reference to loss of steam. The tighter it is the easier it is to raise temperature within a given time, and with a given boiler pressure. In all cases of sterilization the temperatures attained should be carefully tested with a thermometer of known accuracy. It can be seen from the data in the table that steaming

[86] Prucha, M. J., and Harding, H. A., Elimination of Germs from Dairy Utensils Ill. Agr. Exp. Station Bull. 250.

Table 52.—Time and Pressure Necessary to Force 9 to 12 Cubic Feet of Steam Through a ¼-Inch Opening.

Time (Seconds)	Pressure (Pounds)	Steam (Cu. Feet)
10	35	9.100
15	20	9.438
15	25	10.920
20	15	10.374
20	20	12.584
25	10	10.348
25	15	12.948
30	10	12.402
35	5	9.464
60	3	9.984

may have very little real meaning so far as temperatures are concerned.

SMALL TOP OR COVERED PAIL

The small top or covered pail is a very important factor in keeping germs out of milk during the process of milking. It is unfortunate

Fig. 13. Illustrating Manner by Which the Covered Milk Pail Prevents Dirt From Falling Into the Milk.

that the placing on the market of so-called "sanitary" pails which were impractical, has in many cases prejudiced the milk producer

against them. Many milk producers claim that they cannot get their milkers to use small or covered pails, because of the difficulty of milking into them. There are on the market covered pails which are perfectly practical, and when their efficiency in keeping germs out of milk is considered, every dairyman should use them. It is true that it may not be as easy to milk into one of these pails as it is to milk into a large open top pail. However, this objection is not sufficient to make a valid excuse for not using a small top or covered pail. We have yet, after careful inquiry, to find a single dairyman who, having given the small top pail a fair trial, would discard it in favor of the open pail. On certified milk farms and on other farms producing high grade milk, the small top or covered pail is considered indispensable.

These pails have been tried out under poor, medium, and good conditions of milk production and under each condition they have proved their value in producing milk of low bacterial content.

The following table taken from U. S. Department of Agriculture, Bulletin No. 642 (*loc. cit.*), gives a good idea of the value of the small top pail in clean milk production. These figures were obtained when the sanitary conditions of milk production were poor.

Table 53.—Difference in Bacteria in Milk Drawn in an Open Top Pail and a Small Top Pail.

Sample No.	Bacteria per c.c. in Milk		Sample No.	Bacteria per c.c. in Milk	
	Open Pail	Small Top Pail		Open Pail	Small Top Pail
1.....	20,000	9,000	11.....	32,000	24,000
2.....	40,000	20,000	12.....	5,600	2,500
3.....	25,000	11,000	13.....	7,500	3,800
4.....	13,000	16,000	14.....	14,500	2,600
5.....	10,000	3,500	15.....	16,000	12,500
6.....	12,000	23,000	16.....	2,500	2,800
7.....	5,600	2,400	17.....	18,000	14,000
8.....	10,500	45,000	18.....	5,600	2,100
9.....	75,000	35,000	19.....	16,500	7,200
10.....	4,500	3,200	20.....	5,000	2,500

FEEDING HAY AND GRAIN

In clean milk production all operations should be avoided which will stir up dust just before milking time. Among these things may be mentioned feeding hay and grain, sweeping the floor, and even

FIG. 14. Different Types of Sanitary Milk Pails.

brushing the cows with a brush or dry rag. It is not claimed that all of the dust raised by these operations will find its way into the milk pail, but there is a chance that some of it at least will do so, and it is much wiser not to take any chances. In regard to cleaning cows with a brush or dry cloth it is not to be inferred that cows should not be so cleaned. They should be cleaned long enough before milking to allow the dust time to settle.

Stocking[87] has shown that brushing cows just before milking actually increases germ content of milk and the results of his experiments are given in the following table:

Table 54.—Effect of Brushing Cows Just Before Milking, on Germ Content of Milk.

Number of Experiment	Treatment of Cows	Bacteria per c.c. in Milk
No. 1.....	Not brushed before milking	567
	Brushed before milking	900
No. 2.....	Not brushed before milking	242
	Brushed before milking	13,742
No. 3.....	Not brushed before milking	142
	Brushed before milking	758
No. 4.....	Not brushed before milking	225
	Brushed before milking	1,242
No. 5.....	Not brushed before milking	908
	Brushed before milking	1,392
No. 6.....	Not brushed before milking	333
	Brushed before milking	1,292
No. 7.....	Not brushed before milking	467
	Brushed before milking	625

[87] Connecticut (Storrs) Agricultural Experiment Station, Bulletin No. 42 (*loc. cit.*).

Table 54.—Effect of Brushing Cows Just Before Milking, on Germ Content of Milk—(Continued)

Number of Experiment	Treatment of Cows	Bacteria per c.c. in Milk
No. 8	Not brushed before milking	908
	Brushed before milking	1,883
No. 9	Not brushed before milking	363
	Brushed before milking	508
No. 10	Not brushed before milking	842
	Brushed before milking	1,308
No. 11	Not brushed before milking	900
	Brushed before milking	2,533
No. 12	Not brushed before milking	6,321
	Brushed before milking	1,025
No. 13	Not brushed before milking	4,330
	Brushed before milking	4,300
No. 14	Not brushed before milking	350
	Brushed before milking	500
Average	Not brushed before milking	1,207
	Brushed before milking	2,286
Increase as result of brushing		1,079

The same experimenter has also shown that an increase in bacteria will be obtained in milk drawn after feeding hay and grain. In a series of six samples of milk drawn before feeding hay and grain the average bacteria content was 2096 germs per c.c., while in six samples of milk drawn after feeding hay and grain the average was 3506 germs per c.c. This was an increase of 1410 bacteria per c.c. in milk drawn after feeding hay and grain.

DISCARDING FORE MILK

It is well known that the first few streams of milk drawn from the udder contain larger numbers of bacteria than milk subsequently drawn. For this reason in dairies producing milk of high grade, such as certified milk, it is customary to discard the first few streams from each teat. In a large dairy over a long period of time this would mean the loss of a considerable amount of milk. Some producers provide their milkers with small pails and the first few streams are saved for feeding to calves and pigs.

Stocking (*loc. cit.*) has proven that the first two or three streams contain the largest numbers of bacteria,[88] but that the numbers of bacteria per c.c. are comparatively large up to the 5th and 6th streams.

[88] Stocking, W. A., Jr., Quality of Milk Affected by Common Dairy Practices, Bull. No. 42, Storrs Conn.

Table 55.—Bacteria in First Few Streams of Milk from the Udder.

Experiment No.	Bacteria per c.c. in Streams				Strippings
	1 and 2	5 and 6	9 and 10	13 and 14	
1	1940	550	250	275	216
2	25200	5391	285	218	101
3	5491	2096	430	820	144
4	7941	1350	125	216	156
Average	10347	2347	272	382	204

The effect of the numbers of bacteria in the fore milk upon the total numbers found in the entire quantity of milk drawn from the udder is very slight. Stocking has also shown in a series of eight duplicate samples, one drawn from the milk when the fore milk was rejected and one drawn when the fore milk was not rejected, that there was an average of only 23 less bacteria in the former than in the latter. This small number is not within the limit of error of the method of counting bacteria in milk. So far as affecting the total number of bacteria in the entire amount of milk drawn is concerned, it would not pay to reject the fore milk except in the production of certified milk or milk of similar grade.

MILKING UDDER DRY

A factor which exerts a great influence on the germ content of milk is the degree to which all of the milk has been drawn from the udder at the previous milking. The bacteriological influence of milking the udder dry on the subsequent milking is shown by Stocking in Storrs Bulletin No. 42 (*loc. cit.*). So important a factor in producing milk of low bacteria content is milking the udder dry that producers of high grade milk watch this point very carefully. Such producers will not have in their employ milkers who are careless in this respect.

The question of cooling milk is fully discussed in another chapter devoted to that subject. It will simply be mentioned here that it is of vital importance to cool milk as soon as it is drawn and to keep it cold until the milk is consumed. It is often stated that "cleanliness and cold" are the two vital factors in clean milk production.

Table 56.—Effect on the Bacteria Count of the Subsequent Milking When All of the Milk Is Not Removed from the Udder.

Number of Experiment	Treatment at Previous Milking	Bacteria per c.c.	Increase as Result of Not Milking Dry
No. 1	Milked dry	13,825	
	Not milked dry	22,604	8,779
No. 2	Milked dry	6,865	
	Not milked dry	17,607	10,742
No. 3	Milked dry	1,357	
	Not milked dry	2,346	989
No. 4	Milked dry	4,800	
	Not milked dry	12,112	7,314
No. 5	Milked dry	3,129	
	Not milked dry	13,390	10,261
No. 6	Milked dry	21,696	
	Not milked dry	32,296	10,605
No. 7	Milked dry	783	
	Not milked dry	1,371	588
No. 8	Milked dry	3,452	
	Not milked dry	2,153	— 1,299
No. 9	Milked dry	6,812	
	Not milked dry	5,175	— 1,637
No. 10	Milked dry	2,742	
	Not milked dry	4,185	1,443
Average	Milked dry	6,542	
	Not milked dry	11,324	
Increase due to not milking dry		4,779	

Chapter XI

METHODS OF COOLING MILK

No matter what pains are taken in clean milk production, there will always be some bacterial contamination. Most bacteria which are found in milk will not grow at low temperatures, and in order to prevent bacterial growth, market milk should be cooled and kept cold until it is consumed. Even when the so-called "germicidal action" of milk has been taken into account, it has been found that if milk is cooled as soon as drawn it will subsequently have less bacteria per c.c. than if it is allowed to stand for some time without cooling. As a general proposition, milk should be cooled to as low a temperature as possible and not freeze, although temperatures somewhat above freezing will prevent bacterial growth for quite a long time. Even a temperature as high as 50° F. (10° C.) will retard germ growth for a short time. A temperature of 50° F. is mentioned because milk companies frequently require that milk be cooled as soon as drawn to at least this temperature before delivery.

The following table [89] shows the effect of a temperature of 50° F.

Table 57.—A Comparison of the Bacteria Count of Samples of Milk Held at Different Temperatures for One Hour.

Sample	Number of Pounds Milk Used	Bacteria per c.c. in Original Milk	Bacteria per c.c. in Milk Held at 50° F.	Bacteria per c.c in Milk Held at 90° F.	Increase in Bacteria per c.c. of Milk Held at 90° F. Over Milk Held at 50° F.
1.....	40	747,750	727,750	2,499,500	1,771,750
2.....	43	308,900	566,250	1,487,750	921,500
3.....	72	537,500	420,000	7,625,000	7,205,000
4.....	85	575,000	470,000	6,000,000	5,530,000
5.....	85	179,375	158,125	4,920,000	4,761,875
6.....	85	223,125	282,500	760,000	477,500
7.....	80	31,875	65,000	1,675,000	102,500
8.....	64	47,750	110,000	355,000	245,000
9.....	85	20,625	29,375	37,000	7,625
10.....	75	86,875	141,875	1,350,000	1,208,125

[89] Tables Nos. 58, 59, 60, 61 in this chapter were taken from Cornell University Reading Course Lesson No. 102, Cooling Milk, H. E. Ross and T. J. McInerney.

on bacterial growth when the milk was held at this temperature for one hour. The table also illustrates the effect on bacterial growth of holding milk at 50° F. (10° C.) as compared with holding it at 90° F. (32.2° C.).

It will be seen in the above table that there was an enormous increase in bacteria of the milk held at 90° F. over that held at 50° F. It is true that the samples of milk recorded in this table had a high initial bacterial contamination. It is necessary to cool and keep cold milk with a low initial contamination as is shown in the following table when the samples of milk recorded had few bacteria at the beginning.

Table 58.—Effect of High Temperatures on the Bacterial Count of Milk Which Had a Small Initial Count.

Sample	Number of Pounds Milk Used	Temperature (Degrees Fahrenheit) at Which Milk Was Held for 2 Hours	Number of Bacteria per c.c. At Beginning of the 2-Hour Period	Number of Bacteria per c.c. At End of 2-Hour Period	Increase of Bacteria per c.c. Number	Increase of Bacteria per c.c. Percentage
1.....	80	85°	560	4,000	3,440	614.2
2.....	80	89°	2,862	6,335	3,473	121.3
3.....	86	80°	2,967	15,925	13,958	470.4
4.....	86	85°	2,612	24,450	21,838	836.0
5.....	50	85°	3,062	64,700	61,638	2,012.9
6.....	50	85°	362	2,025	1,663	459.3
7.....	60	88°	2,675	28,662	25,987	971.4
8.....	70	84°	500	9,800	9,300	1,860.0

It can readily be seen from the above table that at the end of two hours, even in milk of low initial count, the germ content had increased many fold. If the samples recorded in this table had been held at these same temperatures, they would in a short time beyond the length of time recorded have contained enormous numbers of bacteria per c.c.

One of the methods of cooling milk on the farm is by setting the can into which the milk is strained into a tank of ice water. The proper construction of a milk tank has been discussed in the chapter on Dairy Buildings. The method has one quite serious disadvantage when compared with the use of a special cooler; namely, it is not as rapid as is desirable. Cooling milk in a tank has several distinct advantages, as follows:

1. It is necessary to have a tank for storing milk.

2. Doing away with a special cooler reduces expense.

3. Also makes one less piece of apparatus to wash and thus reduces the chances of contamination.

4. The milk is placed in the final package (the can) as soon as drawn and this reduces the chances of contamination.

In order to cool milk in a can as rapidly as possible, it is necessary to stir the milk frequently. This is clearly shown in Table 59 which compares the effect on rapidity of cooling, of stirring milk at different intervals of time. Can Number 1 was stirred every five minutes and the temperature recorded; Can Number 2 was stirred every 10 minutes and the temperature recorded; Can Number 3 was not stirred at all but the temperature in the center of the can was recorded every 10 minutes; Can No. 4 was stirred continuously and the temperature recorded every 10 minutes. As was to be expected, the milk which was stirred continuously cooled faster than that stirred less frequently and the temperature went lower. A milk producer could not, however, spend the necessary time to stir a can of milk continuously, and it will be noticed that stirring the milk in the can every 10 minutes gave good results, almost as good as the can which was stirred every five minutes. Since it requires in the neighborhood of ten minutes to milk the average cow, stirring the can of milk as frequently as the milk from each cow is strained into the can will give good results.

The so-called conical type of cooler is used to a considerable extent on farms. This type of cooler is made and sold for a comparatively low price and when properly used it is efficient. The conical part of the cooler is hollow and ice and water are placed in this hollow compartment. The receiver into which the milk is strained is slightly larger than the conical part of the apparatus. Small holes are placed in this over-hanging part and the milk runs through these holes onto the conical surface and flows over it, being cooled by the ice water within. A trough around the entire circumference of the cooler collects the milk which is drained from the trough by means of a spout. In order to have coolers of this type work efficiently, it is necessary to stir the ice water frequently within the cooler, or otherwise that part of the refrigerating material which is near the surface would soon become warmed by the

Table 59.—Effect of Stirring Milk at Different Intervals of Time on Rapidity of Cooling.

Experiment	Can	Number of Pounds Ice Used	Temperature of Milk (Degrees Fahrenheit) at 9:00 a.m.	9:05 a.m.	9:10 a.m.	9:15 a.m.	9:20 a.m.	9:25 a.m.	9:30 a.m.	9:35 a.m.	9:40 a.m.	9:45 a.m.	9:50 a.m.	9:55 a.m.	10:00 a.m.
1	1	322	95°	77°	70°	65°	60°	57°	55°	52°	51°	49°	48°	47°	45°
	2	322	95°		73°		62°		56°		52°		48°		46°
	3	322	95°		85°		78°		70°		60°		63°		61°
	4	322	95°		64°		54°		47°		43°		41°		39°
2	1	323	95°	86°	78°	74°	71°	69°	65°	63°	61°	60°	58°	57°	54°
	2	323	95°		80°		72°		65°		62°		59°		55°
	3	323	95°		90°		83°		81°		76°		73°		72°
	4	323	95°		75°		68°		63°		60°		56°		54°
3	1	225	87°	80°	75°	71°	65°	64°	62°	60°	58°	56°	55°	54°	53°
	2	225	87°		75°		66°		63°		59°		57°		53°
	3	225	88°		85°		77°		73°		70°		68°		67°
	4	225	88°		70°		60°		54°		51°		49°		47°
4	1	140	95°	85°	79°	74°	71°	69°	66°	64°	62°	61°	59°	58°	57°
	2	140	95°		80°		72°		67°		63°		60°		58°
	3	140	95°		90°		82°		75°		70°		68°		63°
	4	140	95°		74°		63°		59°		56°		54°		53°
5	1	360	95°	83°	75°	70°	66°	63°	60°	57°	55°	54°	52°	50°	48°
	2	360	95°		75°		67°		61°		56°		53°		49°
	3	360	95°		88°		79°		72°		65°		61°		57°
	4	360	95°		73°		58°		51°		46°		43°		41°
6	1	293	93°	80°	72°	60°	63°	62°	61°	58°	56°	55°	54°	53°	52°
	2	293	93°		73°		64°		61°		56°		54°		52°
	3	293	93°		84°		76°		70°		64°		60°		56°
	4	293	93°		69°		57°		52°		48°		46°		43°

milk and would, therefore, be almost useless as a cooling medium. An opening in the side of the cooler provided with a long handled stirrer makes it easily possible to stir the ice water. Table 60 shows the difference in efficiency of these coolers when the ice water on the inside is stirred and when it is not stirred.

This type of cooler may be used with a running water supply,

FIG. 15. Types of Conical Coolers. This Type of Cooler is Efficient When Properly Used.

as a spout is provided in the bottom of the cooler to which a hose may be attached. An overflow to carry off the water is in the form of a spout, the inlet to which is in the inside of the top of the cooler, and the outlet at the bottom.

Another type of cooler is the tubular type, which consists of a series of tubes, connected at the ends, and the refrigerating material is forced through the tubes, either by gravity or by a power-driven pump. The milk flows from a receiving tank into a trough in

Table 60.—Comparative Results of Cooling Milk with a Conical Cooler When the Water and Ice Were Stirred and Were Not Stirred.

Sample	Number of Pounds of Milk Used	Number of Pounds of Ice Used	Temperature of Milk (Degrees Fahrenheit) at Finish of Experiment		Temperature of Water (Degrees Fahrenheit) at Finish of Experiment		Difference in Temperature of Milk (Degrees Fahrenheit) Due to Stirring
			Water stirred	Water not stirred	Water stirred	Water not stirred	
1.....	85	26	58°	69°	62°	58°	11°
2.....	83	26	60°	70°	58°	50°	10°
3.....	84	35	50°	61°	43°	40°	11°
4.....	86	25	54°	69°	48°	45°	15°
5.....	83	20	56°	68°	56°	50°	12°
6.....	83	35	51°	68°	51°	42°	17°
7.....	82	35	45°	67°	47°	38°	22°
8.....	73	35	50°	66°	50°	60°	16°
9.....	83	35	52°	72°	52°	45°	20°
10.....	81	35	47°	66°	41°	42°	19°
11.....	75	35	46°	66°	41°	41°	20°
12.....	83	35	45°	70°	44°	40°	25°
13.....	84	35	53°	70°	50°	40°	17°
14.....	85	30	47°	63°	47°	41°	16°
15.....	83	25	57°	68°	48°	46°	11°
16.....	73	25	49°	66°	49°	47°	17°
17.....	85	25	57°	64°	52°	52°	7°
18.....	84	25	57°	68°	51°	48°	11°
Average difference							15.4°

which are holes to allow the milk to escape over the outside of the tubes. This trough is so placed that the milk will flow over each side of the tubes of the cooler, and in order to effect this the cooler must be set level. The refrigerating material, such as ice water, should enter the bottom of the cooler and have its outlet at the top, as otherwise the efficiency of the refrigerating material will be lost. If it entered at the top, it would be immediately warmed by the milk and as the milk flowed down over the cooler it would receive little benefit from the refrigerating material inside the tubes.

Since lower temperatures can be obtained with brine and ice than with ice water alone, it is sometimes desirable to cool milk on the farm by the brine method. This can be done only when power is available, as a pump is required to force the brine through the cooler, and since the brine is highly corrosive to iron, a bronze-lined pump must be used for the purpose. A wooden tank for holding the brine is most efficient, since it will not be seriously affected by

the corrosive action of salt, and unless an unusually large quantity of brine is desired a stout oak barrel will be found useful for the purpose. Crushed ice and salt are placed inside the barrel and the bronze lined pump is connected with the barrel near the bottom.

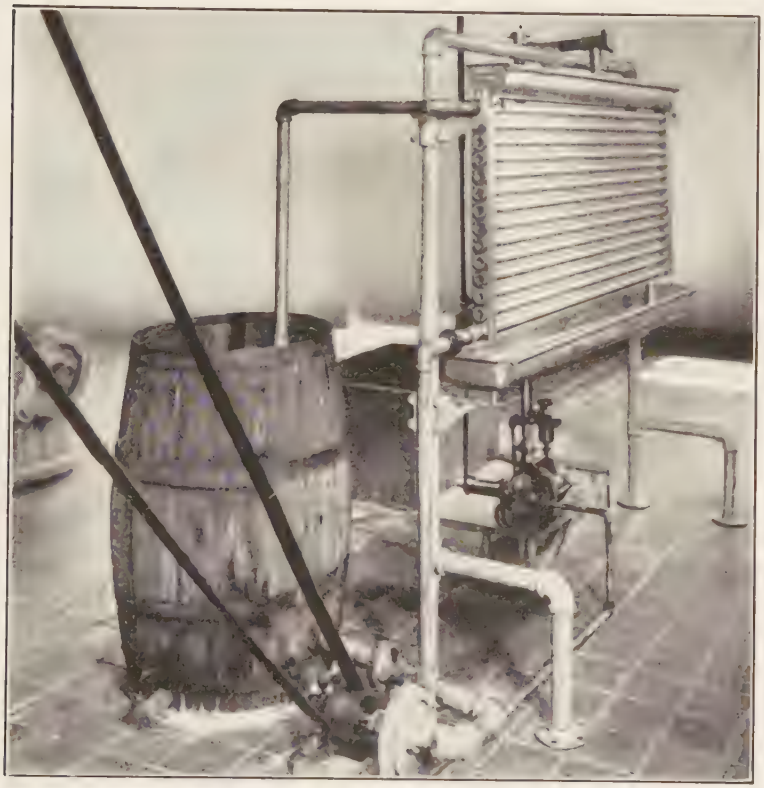

FIG. 16. Tubular Cooler Connected with Brine Barrel and Bronzed Lined Pump.

The mixture is stirred to dissolve the salt and is pumped into the bottom of the cooler and the outlet at the top of the cooler is connected with a return pipe to the brine tank where the brine flows over the ice and is again cooled, making the system a continuous one. A strainer should be placed over the outlet of the brine tank to prevent small particles of ice and foreign material from getting into

the pump and clogging it. Great care should be taken to have the ice washed clean of insulating material such as sawdust or straw, as these materials will not only clog up the pump but the entire line.

MECHANICAL REFRIGERATION

Any discussion or study of refrigeration is essentially a study of heat; for theoretically cold is merely an absence of heat. There are also two kinds of heat to be considered. One is called latent or hidden heat, and which is a result of work done on a body, e.g., in changing its state. The other kind of heat is sometimes spoken of as sensible heat, i.e., we are conscious of it by the sense of touch and we measure it by means of the familiar instrument called a thermometer, and express our measurements in terms of degrees.

It has already been stated that lower temperatures may be obtained with ice and salt than with ice alone. This is because of the fact that when bodies change their state the absorption or evolution of heat is involved. Those substances which absorb heat are called endothermic and those which evolve heat are called exothermic. Salt and ice when mixed to form a solution absorb heat and the melting of the ice is spoken of as fusing. The heat is latent, and therefore the heat absorbed is spoken of as the latent heat of fusion of ice. Also the salt in changing from a solid state into one of solution absorbs heat which is spoken of as the latent heat of solution.

These are the two main reasons why lower temperatures are obtained with salt and ice (brine) than with ice alone. The temperature obtained as a result of mixing ice and salt depends mainly on two factors, the percentage of salt in the solution and the rate at which fusion takes place. The greater the percentage of salt and the more rapid the fusion, the lower the resulting temperature. There is a limit to which salt is soluble in water, the point of saturation being theoretically about 27 per cent. Due to several factors, the point of saturation of common salt, under practical conditions does not usually exceed 25 per cent and this means that there is a limit to the temperatures which may be obtained by a mixture of ice and salt. The following table taken from U. S. Department of Agriculture Bulletin [90] No. 98 gives approximately

[90] Bowen, John T., The Application of Refrigeration to the Handling of Milk, U. S. Dept. of Agr., Bull. No. 98.

the temperatures which may be obtained with different percentages of salt and ice.

Table 61.—Approximate Temperatures Obtained with Different Percentages of Salt and Ice.

Per Cent of Salt in Mixture	Temperature of Mixture 0° F.	Per Cent of Salt in Mixture	Temperature of Mixture 0° F.
0	32	15	11
5	27	20	1.5
10	20	25	—10.0

The unit of heat used by the physicist is the calorie, which is the amount of heat required to raise one gram of water 1° C., at the maximum density of the water, which is 4° C. The engineer uses as a unit for measuring heat the British thermal unit which is the amount of heat required to raise 1 pound of water 1° F. at a maximum density of 39.1° F., and all refrigeration is computed in terms of the B.T.U. system. For purposes of converting one system into terms of the other, it may be stated that 1 B.T.U. is equivalent to 252 calories. Since ice is a substance commonly used for refrigeration and the melting point of ice is always definite, this point is taken as a basis for computation in relation to refrigeration. It requires 144 B.T.U. to melt 1 pound of ice, or looking at the question from the standpoint of refrigeration, 1 pound of ice will furnish enough cold to take the place of 144 B.T.U.

In computing the amount of refrigeration necessary to cool a substance, it is necessary to know the ability of that substance to absorb heat, as compared with some standard. This ability of a given volume of a substance to absorb heat, as compared with the ability of the same volume of some other substance taken as a standard is called the specific heat of the substance. The specific heat of water is higher than that of nearly all other materials, and probably this is one of the reasons why water is chosen as a standard for comparing the specific heat of substances. The specific heat of water is taken as 1, and the specific heat of milk is slightly less than 1, although its ability to absorb heat is variable according to its composition. The specific heat of milk is usually given between .92 and .95, and this means that a given amount of milk would require from .92 to .95 as much heat, to raise its temperature a certain number of de-

grees as would be required by the same volume of water under the same conditions. Looking at the question from the standpoint of refrigeration, a given volume of milk would require .92 to .95 as much ice to cool it a certain number of degrees as would be required by the same volume of water under similar conditions.

The methods of computing the refrigeration which would be available with a certain proportion of ice and salt are given in Chapter 21, problem No. 30. Problem 31 illustrates the method of computing the B.T.U. which would be available if the salt and water are above 32° F.

Problems 32 and 33 illustrate the method of computing the number of pounds ice necessary to cool milk under different conditions.

In computing the amount of ice necessary to cool a given amount of milk, it should be borne in mind that the results obtained are only theoretical. The temperature of the air, the temperature of the water in the cooling tank, and the size of the ice particles are some of the factors which influence the amount of ice required. Very frequently under practical conditions it requires twice as much ice to cool a given quantity of milk as is shown by a theoretical computation.

A COLD STORAGE ROOM

On the ordinary dairy farm a cold storage room is not a necessity. The milk is the only dairy product held and this is done in cans set in the milk tank, usually for only a short time. If, however, the milk is bottled and held for any considerable time, a cold storage room of some kind is a necessity and the same is true if dairy products such as butter or cheese are to be held. The manner in which this is constructed will depend almost entirely on the size of the business and the purpose for which it is intended. If the business is small and not very heavy demands are to be made on it, to put much expense into a cold storage room would not pay. On the other hand, if refrigeration is one of the main features of the business as, for example, in a large ice cream plant, money expended in the proper kind of construction is a good investment. No matter what kind of construction is used, one of the main efforts in building a cold storage room is to prevent the entrance of heat and the escape of cold from the room. Heat is transmitted in three ways: (1) by

conduction, that is, by the molecules in one end of a substance becoming heated and transmitting the heat to the rest of the substance by contact; a good example of this kind would be an iron rod which becomes hot when one end is heated in the fire; (2) heat is transmitted by convection, and this is understood to mean by currents flowing from one place to another, as, for example, a current of warm water flowing to a place which is colder and thereby warming the place which is colder; and (3) heat is transmitted by radiation, this is, a heated body which gives off warmth through the ether which surrounds it. It is impossible to say just where one of these methods of heat transmission leaves off and the other one begins and usually two and not infrequently all three methods are working together.

In building a cold storage room all three methods of heat transmission must be guarded against, and the amount of protection against heat transmission will depend largely on the care with which the building or room is insulated. Many different substances have been tried, for purposes of insulation, among which may be mentioned waterproof paper, matched boards, cement, dead air spaces filled with shavings, granulated cork or sawdust, and cork board.

It is well known that air is a poor conductor of heat and cold and that is the reason why a dead air space is provided. However, convection currents may be set up in this dead air space and to prevent this the space is filled with some light material. The material in this space must be of an elastic nature, resistant to dampness and to rot, and must be as durable as possible. When cork board is used, it should always be treated with some waterproofing material.

In a small dairy plant a room lined with waterproof paper and sealed with matched boards is often used with fair results. In such a case the boards should always be painted with some good waterproof paint. If it is necessary to have a window in the cold storage room, there should be installed two sashes, with a dead air space between them of at least four inches. If possible a cold storage room should be built in the form of a cube as this shaped figure offers less exposed surface than any other geometric figure of the same cubical content. This is shown in the following illustration: a room 10′ x 10′ x 10′ contains 1,000 cu. ft. and has 600 sq. ft.

of surface; a room 5′ x 8′ x 25′ contains 1,000 cu. ft. and has 730 sq. ft. surface.

If possible there should be a small anteroom to each cold storage room as this acts as a dead air space and helps to prevent the passage of heat into the cold storage room.

In any kind of refrigerating room it is best to use expansion doors which are especially designed for the purpose. These doors are well insulated and are designed to expand and contract with changes in temperature. If the room is cooled with brine or with the direct expansion system the pipes carrying the brine or the gas are usually placed along the ceiling or the sides of the room near the ceiling. These pipes are so placed because cold air is heavier than warm air and, therefore, settles. This tends to create air circulation within the room and so equalize the temperature.

If the cold storage room is cooled with ice there are three places of locating the bunker where the ice is held: (1) on the floor; (2) on the walls of the room; and (3) in an overhead bunker. The last location is by far the best as, for reasons already explained, it promotes circulation of air and facilitates drainage. The overhead bunker should be lined with galvanized iron and wooden racks should be provided to prevent the cakes of ice from making holes in the iron. The iron tank should be provided with a drain and the entire bunker should slope toward this drain. It should be stated that all ice should be washed free of sawdust or other foreign material before being placed in the bunker. If the insulating material, such as sawdust, is left on the ice, it will clog the drain and a great deal of the efficiency of the ice is lost because it melts so slowly, that little heat is absorbed from the surrounding atmosphere.

In order to have the cold air circulate from an overhead bunker to the room below it is absolutely necessary to have a baffle plate extend about 24 inches to 30 inches upward on one side of the bunker and the same distance downward into the room. There should be from 6 to 8 inches space between these baffle plates and the walls of the room to allow free passage of the air from the ice bunker overhead to the room below.

Ice stored on the floor of a cold storage room takes up valuable space and keeps the floor constantly damp, which is not desirable.

The same is true of a bunker on the side of the room, although in this case it is possible to line the bunker with galvanized iron and

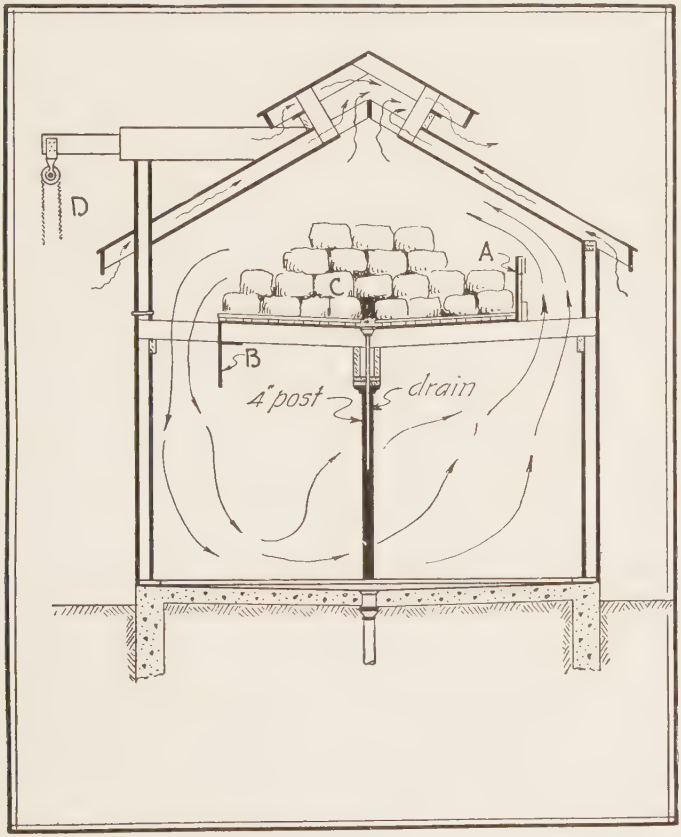

FIG. 16a. Cold Storage Room Cooled by Ice in an Overhead Bunker. A and B are baffle plates which are necessary for air circulation; C, cakes of ice; D, pulley for hoisting ice into bunker.

connect the lining with a drain. Neither the floor nor the side bunkers give as good air circulation as an overhead bunker, when baffle plates are provided.

Chapter XII

MECHANICAL REFRIGERATION AND THE STORAGE OF NATURAL ICE

The use of mechanical refrigeration in dairy work is constantly increasing because of the following reasons:

1. The machines are each year being improved mechanically.
2. Small dairy businesses are merging into larger ones, making the purchase of equipment possible.
3. The high cost of labor in harvesting natural ice.

Mechanical refrigeration has the following advantages:

1. It is cleaner than when natural ice is used and there is less moisture attendant on its use.
2. When once installed, it can be easily available in any room or can be shut off when desired.
3. Lower temperatures can be maintained than with natural ice.
4. It is available in warm climates where natural ice cannot be obtained.
5. Ice manufactured artificially from pure water is wholesome, and is far less liable to carry disease-producing organisms.

Mechanical refrigeration has the following disadvantages:

1. It is expensive to install.
2. It is expensive to operate.
3. The machinery is quite intricate and requires the constant supervision of a skilled engineer.

On account of its cost, it is adaptable only to a fair sized dairy plant.

But the advantages of mechanical refrigeration far outweigh its disadvantages. As a matter of fact it would be impossible to operate many of our large dairy plants without mechanical refrigeration.

The principle utilized in mechanical refrigeration is the same as where a mixture of ice and salt is used; namely, that certain substances on changing their natural state absorb heat. In place of the salt and ice, gas may be utilized, three gases being used for this purpose—ammonia, carbon dioxide and sulphur dioxide. A machine built somewhat like a pump, compresses the gas, the gas passing through a pipe surrounded with cold water; the pressure and low temperature liquefy the gas. After liquefaction results, there is a place in the line of pipe where is located a valve, called an expansion valve, beyond which the pressure is reduced. The expansion valve is opened slightly and the liquid is forced through it under pressure into the line of pipe beyond the expansion valve. Here the pressure is released, causing the liquid to expand, which it does to such an extent that it changes into a gaseous state, thereby absorbing heat from the medium surrounding it. The coils of pipe in which the gas changes from the liquid to a gaseous state, are expansion coils. The expanded gas is now sucked back by the piston in the compressor, is compressed and cooled again to a liquid and in this way the constant expansion and liquefaction of the gas is continued. The line containing the expanded gas has, as would naturally be supposed, very little pressure and it is referred to as the "low pressure line." On the other hand, to liquefy the gas, high pressure is required, and the coils between the compressor and the expansion valve where compression takes place, is called the "high pressure line." The pressure on the expansion side of the line varies from 0 to 30 pounds per square inch, but it is usually desirable to keep the pressure as low as possible. High pressure on the expansion line indicates liquid ammonia in this side of the system and this means loss of efficiency. Different pressures are maintained on the high pressure side but the pressures maintained are usually around 150 to 160 pounds per square inch. Excessive pressures on the high pressure side usually indicate air in the system, due to a lack of whatever gas is used for a refrigerant. This high pressure is usually accompanied by heat, which may raise the temperature to such a point that an explosion results.

If a room is lined with expansion coils, heat is extracted from the air in the room, and thus the room is cooled. Such a method of cooling is called the "direct expansion system." Very frequently

the expansion coils are placed in a tank of brine and the brine is cooled by the expansion system. The brine is then pumped to rooms lined with brine coils, which cools the room. It is used also to cool milk or freeze ice cream.

In the direct expansion system, refrigeration ceases as soon as the compressor is stopped. With the brine system of cooling, the brine may be cooled and then used at a time long after the compressors have ceased running. In cooling different dairy products such as milk or cream, or in freezing ice cream, the brine method of cooling is preferred, because it is usually easier to control temperatures by this method than by the direct expansion method. However, a direct expansion line is sometimes attached to a tubular milk cooler, and those who have used direct expansion in cooling milk report good results. The direct expansion method is neater, since there is no dampness which is always attendant to a greater or less extent on the use of brine, and there is less loss of efficiency of the cooling medium than is the case when a tank of brine is cooled and this in turn is used to cool a room or dairy products. Common salt (sodium chloride) may be used for making brine, but it is very corrosive to the tank in which it is stored and also to the brine coils. Calcium chloride ($CaCl_2$) is less corrosive in its action and for this reason it is usually employed in place of sodium chloride (NaCl).

There are several characteristics which a gas must possess to be a good refrigerant, but two are of chief importance. The first of these requirements is a high latent heat of a vaporization and by this is meant the ability of a gas to absorb a large quantity of heat when it changes from a liquid to a gas. The second requirement of a good refrigerant is its ability to be used at reasonable pressures. If excessive pressures are necessary it requires heavy machinery and there is also more liability of leakage. Ammonia, carbon dioxide and sulphur dioxide are the three gases used in compressors. Ammonia is the gas most frequently used for refrigerating purposes, because it has a latent heat of vaporization of 572.8 B.T.U., which is much higher than that of the other two gases mentioned. Its working pressure is 30 pounds per square inch absolute pressure, which, while fairly high, is not excessive.

The capacity of a compressor is rated in tons, and, contrary to popular opinion, this does not have reference to its ice-making

capacity. Ton-refrigeration has reference to the ability of a machine to extract heat and as a basis of computation the heat required to melt a pound of ice is taken. It requires 144 B.T.U. to melt a pound of ice, and there are 2,000 pounds in one ton. Multiplying 144 by 2,000 we obtain 288,000 B.T.U., which is the equivalent of "one ton" refrigeration. A one-ton refrigerating machine would be one which in 24 hours could produce enough refrigeration to take the place of 288,000 B.T.U.

ICE HOUSES AND THE HARVESTING AND STORAGE OF ICE

On farms, and in many milk plants such as country milk stations, the only practical method of cooling milk is by means of ice. So far as the dairy farm is concerned, there are very few that have a water supply low enough in temperature to cool milk properly without the aid of ice. This is especially true if the milk must be held at the farm for any considerable length of time or is hauled a long distance before delivery at the milk station. The question of the use of ice for cooling milk on the farm is not only a question of final temperature, but it is also one of rapidity of cooling. Rapidity of cooling is essential from the standpoint of efficiency in preventing bacterial growth, and it is also of importance from the standpoint of time saved in the process. This is especially true when the greatest difficulty in cooling comes at a time of year when other work on the farm is so very pressing. Even a few minutes saved is of value in getting other work done. Every producer of milk for city consumption should store ice for cooling milk.

The amount of ice to harvest is very hard to estimate, as conditions vary so widely. Among the important factors affecting the required quantity of ice to be stored are:

1. Amount of milk to be cooled.
2. Prevention of waste in storage.
3. Temperature to which milk is cooled.
4. Method of cooling.

If, for example, the milk is partially cooled with running water, less ice will be required to complete the process. If, in this same instance, the temperature of the water is 48° F. instead of 60° F. much less ice will be required. Oftentimes an estimate of the

amount of ice required for storage is made on a basis of the number of cows in the herd. This is, however, an uncertain basis of computation, since cows vary widely in the amount of milk that they produce. It is much safer to base the calculation on pounds of milk produced, since every producer knows at least fairly well the amount of milk which his herd yields in a year. In order to insure a sufficient quantity of ice it is best to store not less than two pounds of ice for every pound of milk produced.

THE FARM ICE HOUSE

The location of an ice house is important with reference to removing ice for use. When ice has to be removed each day, and in many cases twice a day for the purpose of cooling milk, it should be placed as near as possible to the milk house. It is always a good point to locate the ice house where it will not be exposed more than is necessary to the direct rays of the sun, although it oftentimes is impossible to observe this precaution.

So far as usefulness and serviceability are concerned, the material of which the ice house is constructed is not of great importance. As a matter of fact so far as keeping ice is concerned, it can be stored in a bin with no roof over it at all, and it will keep there as well as in an ice house. Care must be taken to provide between two and three feet of sawdust on the bottom, sides, and top of the ice, and whenever ice is removed the ice in the bin must be well covered again with the sawdust. Such a method of storing ice is, however, unsightly and from that standpoint would be objectionable on a well-kept dairy farm.

If it is desired, an ice house may be constructed and so well insulated that neither the use of sawdust or straw will be necessary. The materials already suggested for use in building a cold storage wall will work equally well for an ice house. In case no insulating material is used around the ice, a small anteroom which will act as a dead air space is useful in preventing warm air from passing into the chamber where the ice is stored. Sometimes ice houses are constructed of concrete with walls six inches thick; and if sand and gravel are convenient, this type of construction may be as cheap as any. Such construction will not, however, do away with the necessity

for the use of sawdust or other insulating material around the ice. Very frequently ice houses are constructed with an ordinary wooden frame and with 2-inch by 6-inch sticks used for studding. The outside is covered with clapboard and painted, to give the building a neat appearance and on the inside rough boards are nailed to the studding to hold the insulating material in place. While this method of construction is cheap, it will serve the purpose if plenty of good insulating material is used. So far as economy is concerned, the cheap construction is generally to be recommended as insulating material for the ice can frequently be had for nothing and it is always cheaper than expensive building materials.

No matter what materials are used in constructing the ice house two features are absolutely necessary for the preservation of ice. One of these features is good ventilation over the top of the mass of ice, and the other is good drainage under the ice to carry away moisture due to melting. If the floor is of concrete, a drain should be provided in the center of the building, and if the floor is of dirt, as is usually the case in most farm ice houses, a layer of cinders at least 6 inches thick should be placed over the dirt. If cinders are not obtainable gravel, as free from fine soil as possible, may be used. Locating the ice house on a light gravelly soil is of great advantage in facilitating drainage.

The floor of the ice house should slope from all four sides toward the center of the building. This aids in drainage and, what is of great importance, it promotes a tendency for the mass of ice to settle towards the center of the building and thus relieves the strain on the sides. If the mass of ice presses very heavily against the sides of the building it may shove them out and ruin the building and this is especially true of cheap construction.

The size of the ice house depends, of course, on the amount of ice to be stored. A cubic foot of ice weighs approximately 57 pounds, and knowing this fact the space required for storing the desired amount of ice can readily be computed. It should be remembered in planning the size of an ice house to allow about 15 inches on the bottom and sides for insulating material. According to Bulletin 1078, U. S. Department of Agriculture, about 45 cubic feet should be allowed for storing and insulating a ton of ice. This is approximately 10 cubic feet more than the theoretical number of

cubic feet required for a ton of ice ($2000 \div 57 = 35 +$ cu. ft.). The following table taken from the above-mentioned bulletin gives the sizes of ice houses required for storing different amounts of ice.

Table 62.—Required Dimensions of Ice Houses for Different Amounts of Ice.

Quantity of Ice (Tons)	Length (Feet)	Width (Feet)	Height (Feet)
10	10	7	7
20	14	8	8
25	14	10	8
30	14	10	10
40	18	10	10
50	16	12	12

One of the first things in obtaining an ice supply is to select, if possible, a pond or stream in which the water is clean. Dirty ice is not only wasteful because of space taken up by foreign material, but from a sanitary standpoint it is undesirable. Foreign material such as mud, leaves, and sticks clogs pumps and drain pipes and makes very difficult the work of keeping the tanks and vats clean where ice is used.

The danger of producing disease by means of contaminated natural ice is not as great as was once supposed. There is, however, some danger of carrying infection in this way, and the cleaner and purer the supply of water from which the ice crop is harvested, the less the danger of spreading infection by means of ice.

All experimental data goes to show that bacteria do not grow in ice and as time goes on they tend to die off. There are four reasons which are given for this fact:

1. The constantly low temperature is decidedly unfavorable for most bacteria.

2. During the process of freezing sedimentation takes place and this mechanically carries organisms to the bottom of the stream, along with the sediment.

3. The ice is a solid medium and, therefore, not as favorable for bacterial life as was the original water.

4. During the process of freezing much of the air is eliminated from ice, and the absence of oxygen makes conditions unfavorable for many bacteria. This is especially true since many of them are aerobes.

The following results obtained by Dr. Park of the New York City Board of Health Laboratories give the effect of freezing in ice on 21 different strains of typhoid bacilli.[91]

Table 63.—Reduction in 21 Strains of Typhoid Bacilli Due to Freezing.

	Average Number of Bacilli in Ice	Per Cent of Typhoid Bacilli Living
Before freezing	2,560,410	100.00
Frozen three days	1,089,470	42.00
Frozen seven days	361,136	14.00
Frozen fourteen days	203,300	8.00
Frozen twenty-one days	10,280	0.40
Frozen twenty-eight days	4,540	0.17
Frozen five weeks	2,950	0.10
Frozen seven weeks	2,302	0.09
Frozen nine weeks	127	0.005
Frozen sixteen weeks	107	0.004
Frozen twenty-two weeks	0	0.000

The following plate by Professor Winslow[92] charted from data obtained by him, shows graphically the reduction in numbers of bacteria due to freezing in ice.

Plate II. Showing Graphically the Reduction in Numbers of Bacteria Due to Freezing.

[91] Park, Wm. H., M.D., New York City, address given before the Natural Ice Association, used by permission.

[92] Winslow, C. E. A., College of City of New York, address given before the Natural Ice Association, used by permission.

Oftentimes, by placing a dam in a very small stream, a pond of sufficient area can be made to furnish enough ice for the summer's use. In doing this, it is frequently necessary to deepen the pond by scooping out the earth. If the land is not stony, considerable dirt can be removed with a two-horse scraper in a short time.

If there is snow or débris of any kind on the surface of the ice it should be removed before cutting is commenced. If the ice has not reached sufficient thickness, the pond can oftentimes be flooded by boring holes in the ice preferably at a point higher than the pond where the cutting is to be done. If the temperature is below freezing, the ice will thicken much faster if the pond is flooded in this way than it otherwise would. The covering of ice over the body of water acts as a protection to keep it from freezing, and the ice will thicken much more slowly if the water underneath is in rapid motion, as in a swiftly flowing stream.

Great pains should be taken to lay out the field in straight lines so that the cakes of ice will be even and of uniform size. Uniformity in size makes the cakes easier to pack in the ice house. More ice can also be packed in a given space if the cakes are regular than if they are irregular. If much ice is to be harvested, a horse-ice plow will be needed. The cakes are not cut clear through but are left of sufficient thickness to bear the weight of the horse, and then after cutting both ways, the cakes are broken off with an ice spud. If only a small amount of ice is to be harvested, a hand ice saw somewhat similar to a cross-cut saw is used. If no ice saw is available, a cross-cut saw with one handle removed is used, although this is not usually as fast cutting as is an ice saw.

The cakes may be of any size desired but a cake 22 inches by 22 inches is quite standard in size. It is not good policy to make the cakes of ice too large as they are heavy to handle and this is especially true of cakes of ice to be used on the farm. Too large cakes tend to wastefulness, as a large cake will be removed from the ice house when only a small amount is wanted, and the rest is allowed to waste.

The following table [93] gives the number of cakes per ton and the number of square feet of cutting space required when the ice is of different thickness. The figures are based on a cake of ice 22″ x 22″.

[93] Bowen, John T., Harvesting and Storing Ice on the Farm, U. S. Dept. of Agr., Farmers' Bull. 1078.

Table 64.—Number of Cakes of Ice Required per Ton and the Cutting Space Required When the Ice Is of Varying Thickness.

Thickness of Ice in Inches	No. of Cakes Required per Ton	Cutting Space Required per Ton Sq. Ft.	Thickness of Ice in Inches	No. of Cakes Required per Ton	Cutting Space Required per Ton Sq. Ft.
4.....	31.3	105.4	14.....	8.9	30.1
6.....	20.9	70.2	16.....	7.8	26.3
8.....	15.6	52.6	18.....	6.4	23.4
10.....	12.5	42.1	20.....	6.3	21.1
12.....	10.4	35.1	22.....	5.7	19.1

The following table gives the weights of cakes of ice 22″ x 22″, when the ice is of varying thickness.

Table 65.—Weights of Cakes of Ice, 22″ x 22″, of Different Thickness.

Thickness of Ice in Inches	No. of Cakes per Ton	Weight per Cake in Pounds
4.....	31.3	63.8
6.....	20.9	95.6
8.....	15.6	128.2
10.....	12.5	160.0
12.....	10.4	192.3
14.....	8.9	224.7
16.....	7.8	256.4
18.....	6.9	289.8
20.....	6.3	317.4
22.....	5.7	350.8

Chapter XIII

THE INSPECTION OF MILK IN THE COUNTRY AND THE DAIRY SCORE CARD

The inspection of market milk may very properly be divided into two parts: the inspection in the country, and the inspection in the city. The former has to do with conditions which surround the production of milk, such as health of the cattle, cleanliness of stables and utensils, and prompt and efficient cooling. The latter has to do with the conditions in the milk plant, such as cleanliness of machinery in which the milk is kept or processed, temperatures and methods of pasteurization, temperatures to which milk is cooled, and methods of distribution to the consumer. Sometimes in small cities and villages, one inspector does both the inspection in the city and in the country and also makes the laboratory examinations.

Whitaker [94] states that the idea of milk inspection dates as far back as 1858 when Massachusetts passed laws forbidding the adulteration of milk. This, of course, relates only to the chemical composition of milk. As the science of bacteriology advanced and the relation of microörganisms to milk became known, the biological side of milk inspection began to receive more attention, and finally, the sanitary quality of milk received far more attention than the chemical composition.

Milk inspection may be carried on by any one of four different agencies or by two or more of them working together. These agencies are the federal government, state governments, municipalities, and private milk companies. The chief aid which the federal government gives in this direction is in questions involving interstate commerce. Some states maintain inspectors whose duties are food control, and milk and dairy products come under this class. Municipalities and private milk companies are very active agents in

[94] Whitaker, Geo. M., The Score Card System of Dairy Inspection, U. S. Dept. of Agr., Cir. No. 199.

milk inspection work. Almost every incorporated city or village has a milk and dairy inspector and the large cities usually have a well-organized division of milk inspection. The milk inspection work of cities is under the general supervision of the city health officer and he in turn is responsible to the City Board of Health.

THE DAIRY SCORE CARD

One of the things which in the beginning hindered the progress of milk inspection was a lack of uniformity in rules and regulations governing milk production. Ideas concerning the necessary conditions for the production of clean milk were not standardized and this led to great confusion, especially on the part of producers. The dairy score card was an attempt to unify and standardize peoples' ideas as to what conditions are necessary on the farm for the production of clean milk.

The dairy score card originated in 1904 with Dr. Wm. C. Woodword, who was Health Officer of the District of Columbia. The year following, in 1905, R. A. Pearson, who was Professor of Dairy Industry at Cornell University, presented a score card, and in 1906 C. B. Lane, Assistant Chief of the Dairy Division, United States Department of Agriculture, offered for consideration a third form of score card. Mr. Lane's card had already been put into practical use and had received favorable comment from health officers and others. It is almost needless to state that at this time the score card was receiving a great deal of attention and many suggestions were offered for changes and revisions.

At this time the Official Dairy Instructors Association (American Dairy Science Association) appointed a committee to study and make recommendations concerning revisions of the score card. This committee consisted of R. A. Pearson, C. B. Lane, and J. M. Truman. The committee met at Cornell University in July, 1908. Their report to the association consisted of a card similar to the one then in use by the Dairy Division, United States Department of Agriculture, and on which several revisions had been made. The association adopted the card as reported by its committee and the Dairy Division also consented to the changes suggested by the association. The card which was adopted was very similar to the one in use by the Dairy Bureau at the present time, although of

course many changes have been made since the time of its adoption. It should be stated that in any consideration of a revision of the dairy score card, the Dairy Bureau and the American Dairy Science Association have always worked in coöperation. This coöperation has made for a great deal of progress.

The dairy score card may be defined as a card on which are enumerated the points which a good dairy should possess and these points are given a numerical value. The numerical numbers given to the different points mean nothing when taken by themselves but are used for the purpose of comparing the value of one point with another for the production of clean milk. For example, the small top pail is given a value of 5, and the construction of utensils 1. Out of a possible 40 points the relative value of these two items, for clean milk production would be respectively 5:1.

The score card is divided into two parts—equipment and method. To the former is given a total value of 40, while to the latter is given a value of 60. The greater emphasis is placed on method because it is more important in clean milk production than is equipment. Furthermore, by giving a greater value to method, it is made possible for those dairymen who are producing clean milk with a small outlay of equipment to obtain a good score. This is a great encouragement to the conscientious dairymen of limited capital to do good work. The dairy score card has advantages and disadvantages for milk inspection work and by most people who have used it the advantages are thought to far outnumber the disadvantages.

ADVANTAGES OF THE SCORE CARD

1. The chief value of the score card is that it is educational. There are four groups of people who are chiefly interested in milk inspection—the board of health and its officers, the milk dealer, the consumer, and the producer, and the score card is educational to all of these groups. By the use of the score card the board of health finds out those rules of sanitation which may be applied to the dairy farm with best results. This is especially true in regard to the economy of the application of sanitary regulations to clean milk production. The same is true of the milk dealer who, as has already been pointed out, often maintains an inspection system of his own. The consumer often feels that the price of milk is very

excessive and does not realize the investment necessary for milk production. Even though the consumer were ignorant of farm operations, a study of the score card should give some idea of the fact that the production of market milk is costly. The producer receives an educational benefit from the score card because it not only teaches him to improve but it points out the relative merits of different dairy operations so far as the production of clean milk is concerned.

2. The score card not only points out defects but it points out the seriousness of the defects. If the milk producer were told that his barn received a total score of 50 and that he ought to improve he would in many cases not know where to begin or where the principal difficulty was located. The score card does away with this difficulty by giving each point a numerical value in relation to its importance in clean milk production.

3. The score card makes a definite ideal toward which the dairyman can work. While this ideal is far above the attainment of the average dairyman, yet the fact that he knows what constitutes perfection in milk production is a constant incentive for him to come as near the ideal as circumstances will permit.

4. The score card judges every dairy on its merits and this helps to do away with hardships or injustices being worked on any particular dairy.

5. The score card encourages the production of clean milk by competition and this is especially true if the results of the score are made public.

6. The score card encourages the dairyman of small capital by placing the greater emphasis on method rather than on equipment. The dairyman who is producing clean milk with a small investment is therefore enabled to obtain a good score for his dairy plant. This is important as in many localities most of the milk supply comes from the small dairies.

7. The score card enables the consumer to judge of the conditions existing on farms where milk is produced and he may then select the dairy which comes nearest his ideal.

8. The score card enables the board of health to recommend good dairies to consumers.

9. The score card periodically brings to the farm a person who is interested in clean milk production. Since the inspector is a representative of the board of health, this should bring the health authorities and the producer into closer relationship.

10. The score card saves time in arriving at the sanitary condition of the dairy. Data obtained at the time of the first scoring may be preserved and this will shorten the time necessary to spend in subsequent scorings.

DISADVANTAGES OF THE SCORE CARD

1. The score card does not in any way indicate the quality of the milk itself. The quality of milk is judged by the equipment and methods used to produce it. This is an undeniable disadvantage and many attempts have been made to formulate a card which would do away with this criticism but, as yet, none of the attempts have been successful. It is very evident, however, that with good equipment and good methods, as indicated by the score card, the chances are greatly in favor of a good quality of milk being produced.

2. The score card is an arbitrary scale and is therefore not strictly applicable to all sections of the country. The requirements for a dairy barn in California where the climate is mild would not be the same as those for a dairy barn in our more northern states where the cold in winter is severe.

3. The argument has often been advanced that many of the standards set on the score card mean nothing because no one can prove whether they are exactly correct. For example, the question is often asked, How is it known that the minimum square feet of glass allowed per cow should be 4? It would be impossible to prove that either 3.7 or 4.3 square feet of glass would not serve the purpose just as well as 4 square feet. However, the fact remains that there must be a minimum somewhere, below which the number of square feet of glass would be an obstacle to clean milk production, for otherwise there would be no basis upon which to work. It is the consensus of opinion of those who have studied the question that 4 square feet of glass is the minimum which should be allowed and hence this is established as a working basis.

The question has often been raised as to the justice and advisability of using the same dairy score card for all grades of milk.

This point has been most frequently discussed in relation to certified milk and ordinary market milk. It is true that much more in the way of sanitation is expected of the high grade milk producer, such as certified milk, than is expected of the ordinary milk producer. However, to have the same numerical score representing two separate ideals would lead to a great deal of confusion, especially in the minds of the city consumers. It would be very difficult to educate the public to the fact that a score of 90 meant one thing on a certified milk farm and another thing on an ordinary dairy farm. It is true that the certified milk producer attains nearer the ideal dairy than does the ordinary milk producer but it is expected that he will do so and he is paid more for this product. This does not lessen the chances of success of the ordinary market milk producer, and the fact that producers of ordinary grades of market milk are judged by the same standards as the producers of certified milk is a stimulating factor in causing the farmer to do better work than he otherwise would do.

In the use of the score card the inspector must aim to be as consistent as possible and must guard against giving two cuts for the same thing. It is very easy to do this on account of the score card being divided into equipment and method. For example, under "equipment," the construction and condition of utensils refers to quality of the utensil and its state of repair. If the inspector finds a piece of apparatus fairly well made and in a fair condition of repair but at the same time very dirty, he is apt unconsciously to deduct for the unsanitary condition under the heading of "equipment," and then make another cut under "method" when the cleanliness of the utensils is being considered.

In scoring dairy barns there are considered certain features which have significance only at certain seasons of the year, and the inspector is sometimes puzzled in regard to allowing credit for these items. Good examples of this kind are window screens in the barn and milk house, and mud holes and stagnant water in pasture fields. Obviously these two features have no significance in winter and in scoring a dairy in the winter months it is best to give full credit for screens and full credit for no contaminating conditions in the pasture field. To do otherwise unnecessarily offers an opportunity

for criticizing the system of milk inspection and such unprofitable criticism is harmful to all concerned.

Those who apply the score card are often criticized for carping over small details, many of which are unessential. This criticism is oftentimes justified but at the same time a very small cut serves to call attention to the deficiency which otherwise might be overlooked by the producer. Furthermore, a certain dairyman may have good conditions, but another dairyman may have something slightly better. Even though the conditions on the first farm are good, it would be an injustice to the second milk producer, where conditions are a little better, to give the same score to both farms. A good illustration of this point is the stable floor. One man may have a new oak plank stable floor. Another farmer has a good cement floor. The first farmer is apt to feel that an injustice is done him if he is given a slight cut for his stable floor, yet no one can deny that the cement floor is the better of the two, and it would be an injustice to the second milk producer not to give him credit for his better floor. In this case the deduction for the wooden floor should be slight and given more to call attention to the fact that there is something better than to inflict a severe penalty. While many of the deductions made by the inspector are small and of themselves do not seem to be of much importance, it must be kept in mind that the production of clean milk is a business of small details. The omission of many details may in the aggregate amount to a matter of considerable importance.

When the use of the score card is first being introduced into a locality the inspector will do well to be not too severe in its enforcement. This does not mean that dirty methods should be condoned or overlooked. It has, however, been pointed out that the chief value of the score card is its educational value, and education is accomplished gradually and by building one fact upon another. If those who enforce the regulations on the score card are arbitrary, it will permanently antagonize the milk producer against its use and its value as an educational factor in clean milk production will be lost. As the purpose of the score card becomes better understood stricter compliance with its rules and regulations may be required and will be accepted with a better spirit on the part of the producer.

One of the most important men in the whole chain of milk in-

spection is the milk inspector, and all too frequently it is impossible to secure the services of a competent man. The first qualification which a milk inspector should possess is training and this refers to both the scientific and practical side of clean milk production. The production of clean milk is based on certain biological facts and if he does not understand these facts the inspector very naturally cannot apply them. On the other hand, not all the methods used in a biological laboratory are applicable on a dairy farm, and it is the difficult task of the inspector to sort out and apply those scientific rules which will get the results desired, and which are at the same time practical of application. Nothing disgusts or antagonizes the milk producer more than to send to his farm, for the purpose of instructing him in methods of clean milk production, a person who knows nothing about the practical side of farming.

The inspector should be a man of tact. Even though the rules and regulations required by the board of health are fair and reasonable, many milk producers are prejudiced against them, and will not comply with them if they can avoid doing so. In such a case the easiest thing to do is for the inspector to refuse to accept such a producer's milk, but this should be done only as a last resort. Such a course very naturally antagonizes the producer more than ever, and a disgruntled producer in a community may infect an entire neighborhood and do the cause of clean milk production a great deal of harm. To convert such a producer to the cause of clean milk production requires tact and patience on the part of the inspector far above that which is possessed by the ordinary individual. The inspector should also be a man of good judgment. While the score card has stated definite values for certain specified features in milk production, it is not always applicable to conditions and is not infallible. In short, the score card is very often a guide rather than an arbitrary rule. In such cases good judgment on the part of the inspector is of the greatest necessity in rendering fair decisions on the different dairies which he scores.

It would be desirable if the milk inspector could visit the dairies at milking time, as the conditions which prevail at that time are most important and the score card is supposed to be applicable to conditions which exist at that time. For economic reasons it is impossible for the inspector to visit each dairy while milking is in

progress, as this would mean that he could visit only a very few dairies each day. He, therefore, has to judge of the conditions which would prevail at milking time by the conditions which prevail at the time of his visit. To do this and be fair to producers and consumers alike requires keen foresight and excellent judgment.

It is a fact that in many cases the salary paid for the services of milk inspectors is inadequate to serve and maintain a competent man. This is unfortunate and we believe is shortsighted economy if it is the intention to make the milk inspection service worth while.

While the score card has several objections and is still open to improvements it cannot be denied that it has been one of the leading factors in clean milk production. Some investigators claim that there is absolutely no connection between barn scores and the bacteria count of the milk produced in them. Brew,[95] in an investigation of this subject, scored 34 dairies by three different types of score cards and did not find any relation between the score of the dairy and the quality of the milk produced in them. It is a well known fact that many times a barn with a high score will produce milk with a high bacteria count; and vice versa a barn with a low score will produce milk of a low bacteria count. Other investigators state that in case of a large number of dairies there is a direct relation between barn scores and the bacteria count of the milk. It is stated[96] that in Montclair, N. J., after the score card system of inspection was introduced, the average bacterial count of the milk fell from 91,000 per c.c. to 53,000 per c.c. This was in a period of two years. The following table taken from the same source as the above information gives the improvement in barn score of six cities in the United States after the score card system was established.

Table 66.—Gain in Barn Scores in 1 Year in Different Cities in United States.

Cities	Average Scores		Average Points Gained
	1909	1910	
Los Angeles, Calif.	55	63	8
Glens Falls, N. Y.	49	62	13
Concord, N. H.	40	46	6
Hudson, N. Y.	40	50	10
Clinton, Iowa	56	67	21
Portland, Oregon	36	45	10

[95] Brew, James D.,, Milk Quality as Determined by Present Day Score Cards, N. Y. State Experiment Station, Geneva, N. Y., Bull. 398.

[96] Whitaker, G. M., The Score Card System of Dairy Inspection, U. S. Dept. of Agr., Cir. No. 199.

It is of course only natural that the greatest improvement in both barn score and bacteria count would take place during the first year that a system of milk inspection was established. This is well illustrated in the case of Richmond, Va. (Cir. 199 U. S. Dept. Agr. *loc. cit.*). In May, 1909, the average barn score of the dairies was 41.5 and in February, 1908, the average barn score was 69.6, an average gain of 28.1 points. At the beginning of 1909 the average barn score was 76 and at the close of the year it was 79, a gain of only 3 points.

USE OF THE SCORE CARD

EQUIPMENT *

Cows.—The health of the herd is one of the most important items on the score card because an unhealthy herd might mean the transference of some of our most serious diseases through the milk supply. The cows' udders should receive special attention and should be examined for lumps, unsound quarters and cow pox or any eruption or sores. Some inspectors make deductions for any physical deformities, as, for example, the loss of an eye, large joints on the front legs due to bruises, and lameness due to spavins. We do not think this should be done, but only those physical imperfections should be passed on by the inspector which affect or are liable to affect the milk supply. A great deal of emphasis is placed on tuberculosis and greater cuts are given for cows which are not tested for tuberculosis than for those which have been tested at stated intervals. There is no question but what tuberculosis is one of our worst cattle diseases, but the inspector should not allow the emphasis which is placed on this disease to blind him in regard to others which may exist.

In some localities the physical examination of herds by a veterinarian has been used to determine the health of the animals. A great deal of work has been done by Dr. V. A. Moore and his associates, which shows that a thorough physical examination by a competent veterinarian is of great aid in detecting those animals which have tuberculosis in a stage far enough advanced to be

* In discussing the points on the score card, only the mechanical application of the card will be taken up, and buildings and utensils will be mentioned only when necessary to illustrate the various items on the card. Dairy buildings and dairy utensils will be discussed in subsequent chapters.

EQUIPMENT	SCORE		METHODS	SCORE	
	Perfect	Allowed		Perfect	Allowed
COWS			**COWS**		
Health	6		Clean	8	
Apparently in good health	1		Free from visible dirt, 6		
If tested with tuberculin within a year and no tuberculosis is found, or if tested within six months and all reacting animals removed	5				
If tested within a year and reacting animals are found and removed	3				
Food clean and wholesome	1				
Water, clean and fresh	1				
STABLES			**STABLE**		
			Cleanliness of stable	6	
			Floor	2	
			Walls	1	
			Ceiling and ledges	1	
			Mangers and partitions	1	
			Windows	1	
			Stable air at milking time	5	
			Freedom from dust	3	
			Freedom from odors	2	
Location of stable			Cleanliness of bedding	1	
Well drained	2		Barnyard	2	
Free from contaminating surroundings	1		Clean	1	
Construction of stable			Well drained	1	
Tight, sound floor and proper gutter	4		Removal of manure daily	2	
Smooth, tight walls and ceiling	2		To 50 feet or more from stable.		
Proper stall, tie, and manger	1				
			MILK ROOM OR MILK HOUSE		
Provision for light: Four sq. ft. of glass per cow	4		Cleanliness of milk room	3	
Three sq. ft., 3; 2 sq. ft., 2; 1 sq. ft., 1. Deduct for uneven distribution.					
			UTENSILS AND MILKING		
Bedding					
Ventilation	1		Care and cleanliness of utensils	8	
Provision for fresh air, controllable flue system	7		Thoroughly washed	2	
Windows hinged at bottom, 1.50; sliding windows 1; other openings .50.	3		Sterilized in steam for 15 minutes	3	
			Placed over steam jet or scalded with boiling water	2	
			Protected from contamination	3	
Cubic feet of space per cow, 500 feet	3		Cleanliness of milking	9	
Less than 500 feet, 2; less than 400 ft., 1; less than 300 feet, 0.			Clean, dry hands	3	
			Udder washed and wiped	6	
Provision for controlling temperature	1		Udders cleaned with moist cloth, 4; cleaned with dry cloth or brush at least 15 minutes before milking, 1.		
UTENSILS			**HANDLING THE MILK**		
Construction and condition of utensils	1		Cleanliness of attendants in milk room	2	
Water for cleaning	1		Milk removed immediately from stable without pouring from pail	2	
Clean, convenient and abundant.			Cooled immediately after milking each cow	2	
Small-top milking pail	5		Cooled below 50° F.	5	
Milk cooler	1		51° to 55°, 4; 50° to 60°, 2.		
Clean milking suits	1		Stored below 50° F	3	
			51° to 55°, 2; 56° to 60°, 1.		
MILK ROOM, OR MILK HOUSE					
Location free from contaminating surroundings	1		Transportation below 50° F	2	
Construction of milk room	2		51° to 55°, 1.50; 56° to 60°, 1.		
Floor, walls and ceiling	1		If delivered twice a day allow perfect score for storage and transportation.		
Light, ventilation, screens	1				
Separate rooms for washing utensils and handling milk	1				
Facilities for steam Hot water 0.5	1				
Total	40		Total	60	

Equipment..... + Methods..... = ...Final Score

NOTE 1 — If any exceptionally filthy condition is found, particularly dirty utensils, the total score may be further limited.

NOTE 2 — If the water is exposed to dangerous contamination, or there is evidence of the presence of a dangerous disease in animals or attendants, the score shall be 0.

FIG. 17. Obverse Side of Dairy Score Card.

BOARD OF HEALTH

SANITARY INSPECTION OF DAIRY FARMS

MARKET MILK PRODUCTION

SCORE CARD

Indorsed by the Official Dairy Instructors' Association.

Owner or lessee of farm.....

P. O. address.....State.....

Total number of cows.....Number milking.....

Gallons of milk produced daily.....

Product is sold by producer to families, hotels, restaurants, stores,

to.....dealer

For milk supply of.....

Permit No..... Date of inspection.....192..

REMARKS .....

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(*Signed*).....

Inspector

FIG. 17a. Reverse Side of Dairy Score Card.

spreaders of the disease. It has never been intended by those who are advocates of the physical examination that it should take the place of the tuberculin test but merely supplement it. There is abundant proof, both in European countries and in the United States, that where the physical examination has been thoroughly and systematically employed, great progress has been made in eliminating bovine tuberculosis from the herds. Dr. Moore [97] states that while the physical examination will not detect more than from 1 to 5 per cent of infected animals which may be in a herd at any one time, yet he believes it will detect from 80 to 85 per cent of these animals which are actually spreading the germs of tuberculosis. By making frequent physical examinations and removing all suspicious cases, those animals which are doing the actual harm are eliminated and this is a big step in eradicating tuberculosis from our herds.

The physical examination has another distinct advantage in that it takes into account, so far as they can be detected by external observations, all bovine diseases. This is of extreme importance in safeguarding a milk supply.

On the dairy score card there are no values suggested for the application of the physical examination by a competent veterinarian. This leaves the inspector very much in doubt regarding the emphasis which should be placed upon it and, in some cases at least places him in a very difficult situation. It has been suggested that approximately 80 per cent of the values now allowed for the tuberculin test be allowed for a thorough physical examination. Others feel that this is giving the physical examination more value than it deserves. One thing is very certain, and that is the physical examination must be thoroughly and conscientiously done by a competently trained man, or it will be of little value.

Food and water.—The food and water should be clean and wholesome, as poor feed and filthy water might cause digestive troubles in the cow and thus affect the milk supply. Also spoiled fodder or feed often carries yeasts, molds and spore-bearing bacteria, and if these were prevalent in the stable they might easily affect the milk supply.

[97] Moore, V. A., The Value of Physical Examination and Clinical Diagnosis in the Control of Tuberculosis in Cattle. 16th Annual Report U. S. Live Stock Sanitary Association.

Stables.—The location of the stable is important, as anything which gives a liability of contamination is a constant menace to a milk supply. Under the heading of contaminating surroundings would be included privies, pig styes, chicken yards, dusty roads, etc. The barn should if possible be on well-drained soil and if the soil is of clay or for any reason has a tendency to hold water, drainage should be provided. The barn should not be built in a depression where surface water will tend to flow toward the building.

STABLE CONSTRUCTION

The proper construction of the stable is a great aid in producing clean milk. Tight ceilings prevent dust from falling from above into the stable, and smooth ceilings and walls and the absence of ledges tend to prevent the collection of dust.

The floor is very important in clean milk production, and this has already been discussed under general directions for use of the score card.

The gutter should have the following qualifications: (1) It should be large enough to hold the droppings and liquid manure. (2) It should not be too deep or too large, so that it occupies an undue proportion of space. (3) It should be tight to hold liquid manure. (4) It should be wide enough to admit the easy use of a shovel.

The tie or stanchions should be judged from two standpoints in scoring a dairy barn: (1) They should be comfortable as possible, because anything which contributes to the comfort of the cow tends to contribute to her health. (2) They should have a minimum amount of ledges so as to offer as small a surface as possible for the collection of dust and dirt.

The manger should be large enough to hold a sufficient quantity of roughage for one feeding and it should not have cracks and crevices where grain and other materials can collect and sour and hence become unsanitary.

Bedding should be judged under equipment so far as quantity and quality are concerned. Its cleanliness should be left until methods are considered. There should also be considered at this time the suitability of the particular kind of bedding used. For example, horse manure does not make good bedding, although we do not

think this applies to the use of limited amounts in the gutters for absorbing liquid manure.

PROVISION FOR LIGHT

The main points in judging for light are the necessary square feet of glass and the distribution. It should be so distributed that all parts of the stable receive sufficient light to make the proper performance of work easily possible, and readily to see whether there is a collection of dirt. Cloth curtains, used for ventilation, should not take the place of a window. On the score card no provision is made for giving credit for fractions of square feet of glass. This should be done, as, for example, a barn having 3.5 square feet of glass per cow is better lighted than one having only 3 square feet per cow. The score allowed for different amounts of square feet of glass should be proportional to that allowed for a perfect score.

PROVISION FOR VENTILATION

In considering ventilation there are usually three types to consider: the King system, the cloth curtain system and various kinds of flues and openings. In all types, the provision for controlling temperature is important. Many modifications of a flue system give an exchange of air but in cold weather give no protection against a low temperature. It should also always be remembered that cubic feet of air space and ventilation are not necessarily synonymous.

In making deductions for cubic feet of air space, we do not believe that the deductions should be as arbitrary as suggested on the score card. If a stable has 490 cubic feet of air space, it certainly should receive more credit on the score card than one which has only 400 cubic feet. We see no reason why the cut should not be in proportion to the cubic feet of air space which the stable has.

In computing the number of square feet of light and the cubic feet of air space per cow, it is safest to use the number of stanchions as a basis for computation rather than the number of animals in the stable. If at the time the inspection is made the stanchions are not filled, a barn might receive a high rating in regard to light and cubic feet of air space. Subsequently all of the stanchions may be filled and under these conditions the light and ventilation might

be very inadequate, and in this way a false record of actual conditions would be on file in the office of the board of health.

UTENSILS

The utensils should be well constructed and free from cracks and crevices. They should not be battered and dented so that they are difficult to clean. It should be borne in mind that no cut should be made here for unclean utensils as this should be done under methods. The rest of the items mentioned under utensils are selected from many others which might be named because they are considered very important in producing clean milk. Water taken directly from a stream has the possibility of causing serious contamination and even water which is used for drinking purposes may contain bacteria which when brought into contact with milk will putrefy it.

Convenience and abundance of water are also necessary to clean milk production. Years of experience have taught that if water is not abundant, or if it is difficult to get, enough of it to keep things clean will not be used. Special milking suits tend to prevent contamination of milk, which would come from the clothing of the milker, and while the reference is in regard to any kind of contamination, it is especially important in case the milk has been in contact with any infectious, contagious disease.

MILK ROOM OR MILK HOUSE

In caring for milk it is necessary to have a clean place free from dirt and flies, and a place which precludes the possibility of milk taking up odors. A house or room specially designed for holding milk and which is used for nothing else is the only place which will serve this purpose. All of the comments which have been made in regard to the location, light, ventilation and construction of the stable will apply to the milk house and it is not necessary to repeat them.

Separate rooms for handling milk and washing utensils are required to prevent contamination of milk by utensils which have been where there was an infectious, contagious disease. The scoring of this point will sometimes give the inspector trouble as sanitarians generally are against having milk utensils washed in the kitchen, because of possibility of contamination from various diseases, such

as measles, mumps, whooping cough, scarlet fever, diphtheria and typhoid fever. The household where the milk is produced does not always realize the danger of contamination and are apt to feel that the objection to washing dairy utensils in the kitchen is a criticism on the cleanliness which prevails there.

Steam is more effective in sterilization than is hot water, but it cannot be denied that in most small dairies the generation of steam would be uneconomical and hot water must therefore be used. The kitchen is the most convenient and economical place to produce hot water on a small dairy farm, and for these reasons very few small dairies have any place other than the kitchen in which to wash dairy utensils. Hot water of 180° F. or above is very effective in destroying germ life if it is properly used. We believe if utensils are washed in the kitchen a small cut should be made to call attention to the fact that a separate place for washing dairy utensils is best. However, the cut should not be so severe as to discourage good work which is being done, even though no separate place other than the kitchen is provided for washing utensils.

METHODS

Cows.—The freedom from visible dirt means the absence of manure, mud, bits of bedding and straw which might fall into the pail. A cow might be free from all of these and yet have her hair full of dandruff and dust, which could easily fall into the milk pail and carry with it a great deal of contamination. The hair about the udder and flank should be clipped short to make the lodgment of dust and dirt more difficult. The inspector will have to use his own judgment in regard to the cuts which should be made, and the cuts will be based not only on the cleanliness of the cow but also on the fact as to whether or not the hair on the flanks and udder have been clipped.

Stable.—The stable should be free from manure, dust, bits of fodder and cobwebs. There should be no dried manure on the floor under the bedding, as this indicates that the stables at some time have not been cleaned as thoroughly as they should have been. The same is true of dried manure on the walls behind the cows.

The judging of the condition of the stable air at milking time is difficult if the inspection is made at a time when milking is not

going on. It has already been pointed out that it is not always possible to make the inspection at this time, and the only thing to be done is to have decision on the general conditions of cleanliness. If the floor is not sprinkled before milking time, a small cut should be made, as this is done in the highest grade dairies.

The bedding should be clean and should not be unduly dusty, as might, for example, be the case with musty straw. Shavings are usually considered freer from germ life than is straw, but they are not as desirable from the standpoint of a fertilizer as they are slow to decompose when spread on the land.

The barnyard should be free from manure, mud or water, and if it is well drained the natural tendency to have a wet and muddy yard is obviated.

The removal of manure to at least 50 feet from the stable is a precaution against its working back into the stable and makes it less possible for contamination to be carried by flies. It is of course best where practicable to remove the manure daily to the field where it is to be used, but if this cannot be done a specially covered manure pit should be provided. This is true not only from a sanitary point of view but also from the standpoint of economy in conserving the value of the manure. The location of the manure pit should also be taken into account. If it is in an exposed place and in the path of the prevailing winds, its chances of causing contamination are much greater than if it is sheltered.

MILK ROOM OR MILK HOUSE

The cleanliness of the milk house needs no special comment other than those already given for the barn. The kind of dirt present will probably be different from some kinds found in the barn and may consist of cobwebs, dust, mold and sawdust from ice used. Dried milk may also in some cases be found on walls, and the presence or absence of flies should be noted. If a milk tank is used for cooling and storing milk, its condition should receive careful attention. Stagnant or dirty water should not be tolerated and the sides and walls of the tank should be clean. The air in the milk house should be free from dust and odors and special attention should be given to sewer gas which is sometimes present due to a faultily constructed drain.

UTENSILS AND MILKING

Clean and sterile utensils are an absolute necessity in producing clean milk. The inspector can of course tell if the utensils are clean, but he has no way of knowing whether the utensils are sterile, as to determine this would take more time than would be practicable in milk inspection work. If, however, the milk coming from a certain dairy has a low bacterial count, it is a good and almost sure indication that the utensils are cared for as they should be. As has already been mentioned, steam is more efficient than hot water for purposes of sterilization. The value of boiling water for cleaning dairy utensils should be emphasized, however, as on most dairy farms the production of steam is uneconomical and the proper use of boiling water will greatly advance the cause of clean milk production.

The hands should be washed before milking and it is of course very desirable to wash the hands after milking each cow. Milking with wet hands should not be tolerated.

Washing the udders and wiping them with a clean towel is the best way to prevent dirt from falling from the udder into the milk pail. Wiping the udder with a damp cloth removes some of the dust and dirt from the udder, but it also causes some of it to stick to the udder and so prevents its falling into the milk pail.

If the practise is followed of wiping the udder with a dry cloth there should be emphasized the necessity of performing this operation long enough before milking to give the dust time to settle. If this is not done, so much dirt may be stirred up that the purpose of the practise may be defeated.

HANDLING THE MILK

If the milkers strain the milk which they draw, they naturally will be no cleaner in the milk room than they are in the stables. If, for example, they do not have special milking suits, a slight cut should be made for attendance in the milk room.

Removing the milk from the stable to strain it causes less liability of the absorption of odors. Moreover, cooling milk as fast as it is drawn is desirable and straining milk in the stable would practically eliminate the possibility of cooling milk as fast as it is drawn.

The necessity of cooling milk and storing it at a low temperature is too well known to need any discussion. The inspector should always carry a tested thermometer in order to check up on temperatures, as very frequently the milk producer does not have a thermometer, and is guessing at temperatures. The necessity for putting up ice should also be emphasized to the milk producer. It is desirable to cool milk as low as possible and not freeze it and very few natural water supplies are cold enough to cool milk properly. They may be used to partially cool milk, and then the process may be completed with ice.

Chapter XIV

THE CITY INSPECTION OF MILK

The principles underlying city milk inspection are the same as those of country inspection, and the purpose of both groups of inspection is the same; namely, the improvement of the milk supply. To best accomplish this purpose, the two groups must coöperate and in some cases the duties of the two groups will more or less overlap.

The qualifications for a city milk inspector are the same as those of the country inspector. He must be well trained and this training should include technical knowledge of milk plant operations, such as washing utensils, bottling, cooling and pasteurizing. He should also understand the principles of bacteriology and the relation of bacteria to milk, even though he does not do laboratory work. He must be tactful and at the same time keen and alert to detect evasion of ordinances.

The duties of the city milk inspector will vary in different cities, and usually the variation will depend on the size of the city. In large cities some inspectors collect the samples, others make only laboratory examinations and others inspect dairy plants. Sometimes milk sold in cities is prepared for market in a country plant, and the city has to send inspectors into the country to inspect these plants. They usually have nothing to do with barn inspection or with the production of milk on the farm. The city inspector also has to supervise the milk as it is received at the city terminals, to see that it arrives properly refrigerated and that it is not held unduly long. He also must keep check on cans and bottles which are returned to country plants to see that they are properly washed before shipment. This last-mentioned duty is a very important one.

Another duty of milk inspectors is the supervision of milk sold in stores and restaurants. In many cities, especially the larger ones, restaurants and stores handle bulk milk both on account of the profit

which is made on the milk and also in case of the stores because it stimulates trade for other merchandise which they handle, such as groceries and meats. The customer comes after the milk, bringing his own container, and in some places this idea has been encouraged because it lessens the expense of delivery and so enables the consumer to get milk cheaper than he otherwise could. In supervising this milk supply, the inspector must see that the milk is stored in a suitable place which will not be a constant source of contamination. In stores there is the constant temptation to keep bulk milk in close contact with fish, meat and vegetables by means of which milk might receive contamination and from which it might easily take up odors.

The kind of dipper used to measure out the milk is important. It should be without seams, and the handle should be of such a length that milk can be dipped without danger of contamination by the hands of any one serving it. The place where the dipper is kept is also important; if laid on an unclean surface, it might easily carry contamination into the milk. Perhaps one of the best places to keep this dipper is in the can from which milk is dipped. The cabinet in which milk is stored should be of sufficient size to hold the right amount of ice for keeping milk cold. The cabinet should be so constructed that it can be readily cleaned and it should always be provided with a proper drain. Most boards of health are very particular about this last point.

In most cities milk is delivered by the wagons at a very early hour, many of the deliveries beginning at 3 o'clock in the morning. Also the trains bringing milk to the cities usually arrive during the night or the early hours of the morning, thus making the work of collecting samples a sometimes arduous task, especially in cold weather.

The manner in which milk or cream samples are taken for examination by a board of health varies in different cities. The amount which is taken will vary according to the purpose for which the sample is intended. If only a bacteriological examination is required a few cubic centimeters, say 10 c.c., will be sufficient. If the same sample is to be used for both bacteriological and chemical examination, a larger sample, usually not less than 125 c.c., is taken. The sample bottles in which the milk is placed must, of course, be sterile and it is a good plan to wrap them in paper until they are used in order to prevent contamination. The bottles having ground

glass stoppers are best, although some inspectors use cotton plugs. The sample bottles should be packed in ice as soon as the sample is placed in it, as this will prevent any possible increase in bacteria.

The manner of taking the sample is a feature which has given a great deal of trouble. Both for a chemical and bacteriological examination, it is necessary to mix the milk thoroughly and this is oftentimes difficult to accomplish in such a way that it will not

BOARD OF HEALTH

MILK INSPECTION

STREET RECORD

Name of dealer.....
Name of producer.....
Sample No. .....
Date of taking sample.....
Hour of taking sample.....
License on wagon .....
Temperature outdoors.....
Temperature of milk.....
Morning's or night's.....
Whole or skimmed claimed.....
Can or bottle.....
Amount bottled .....
Appearance .....
Odor .....
REMARKS:—

FIG. 18. Card for Keeping Records of Samples Taken on Street for Purpose of Inspection.

contaminate the sample. If the sample is taken from a can, the dipper which is ordinarily employed for dipping is used to stir the milk in the can and to pour the sample into the sterile bottle. Objection is often made to this method on the grounds that the dipper might be contaminated and thus bacteria would be in the sample which were not in the original milk. Also by taking the sample in this manner the can of milk would be contaminated. Instead of being objections, these arguments are really in favor of this method of sampling. If the contamination were on the dipper used in serving customers, it would get into the milk eventually and it is a good thing to have this contamination represented in the sample

taken for examination. Sometimes special stirring devices are used, such as special dippers, paddles, and stirrers with spouts on them large enough to dip milk. In some cases sterile glass tubes of large diameter are used for drawing the sample. These are plugged with cotton and wrapped in paper to prevent contamination and as a matter of fact all of the dippers and stirrers referred to above must be protected from contamination and this is usually done by wrapping them in paper before sterilization. If the apparatus used is small enough, as in the case of the glass tubes, metal cases may be provided and these are best made of copper.

Milk sold in bottles is hard to sample because of the difficulty involved in thoroughly mixing it. In cold weather especially, the cream rises and sticks to the cap and it is almost impossible to dislodge it. For this reason, an entire bottle of milk is usually taken for examination. Sometimes the inspector pays for this milk and sometimes not. If the samples are not taken too frequently, few dairymen object in having an occasional bottle of milk taken for

DEALER				PRODUCER								
YEAR	MONTH & DATE	A.M. OR P.M.	CAN OR BOTTLE	TEMP.	PER CENT ACID	PER CENT FAT	PER CENT T.S.	BACTERIA	GRADE	BARN SCORE		DATE OF SCORING
										EQUIP.	METHOD	

FIG. 19. Card Suitable for Keeping on File City Milk Records.

purposes of inspection. In the smaller cities and villages the milk dealers are glad to have these samples taken in order that they may keep track of the quality of milk furnished by the different producers from whom they purchase milk.

BOARD OF HEALTH

MILK INSPECTION

REPORT OF STREET SAMPLES

Name of Dealer.....
Name of Producer .....
Sample No. .....
Date of taking sample.....
Hour of taking sample.....
License on wagon.....
Temperature outdoors .....
Temperature of milk.....
Morning's or night's.....
Whole or skimmed claimed.....
Can or bottle.....
Amount bottled .....
Appearance .....
Odor .....
Per cent fat.....
Specific gravity at 60° F.....
Solids not fat.....
Total solids .....
Iron test for formaldehyde.....
Tumeric test for borax.....
Relative amount of insoluble dirt.....
Per cent acid at delivery.....
Per cent acid in 24 hours at 50° F.....
Laboratory No. .....
Bacteria per c.c. of milk.....
Total bacteria .....
Acid bacteria .....
Per cent acid bacteria.....
Rapid liquefiers .....
Slow liquefiers .....
Per cent of liquefiers.....

FIG. 20. Card for Making Report of Samples Taken for Purposes of Inspection.

The amount and kind of data collected by milk inspectors varies in different places. The amount and kind of data kept by both inspector and the chemist and bacteriologist should be sufficient to give all needful information in regard to the samples, yet it should not be so minute as to be burdensome. Care should be taken to eliminate all possible details and at the same time have the records complete.

THE CITY MILK PLANT SCORE CARD

A score card specially designed for the work has been devised for judging city milk plants. In principle it is the same as the dairy score card and differs from that card only in the items on it and the values given to the different items. The city milk plant score card, like the dairy score card, is divided into two divisions, equipment and method, and 40 is allowed as a perfect score for equipment and 60 allowed for method.

The score card for city milk plants has not received the attention and consequently is not as well known as is the score card used in judging dairy barns.

SANITARY INSPECTION OF CITY MILK PLANTS

SCORE CARD

Owner or manager.....

Street and No.....

City..... State.....

Trade name .....

Number of wagons..... Gallons sold daily { Milk..... / Cream .....

Permit or License No.....

Date of inspection....., 192

Remarks: .....

.....

.....

....., *Inspector.*

FIG. 21. Reverse Side of Score Card Used in Judging City Milk Plants.

EQUIPMENT	SCORE	
	Perfect	Allowed
BUILDING:		
Location: Free from contaminating surroundings	2	
Arrangement	7	
Separate receiving room 1		
Separate handling room 2		
Separate wash room 1		
Separate sales room 1		
Separate boiler room 1		
Separate refrigerator room 1		
Construction	12	
Floors tight, sound, cleanable 2		
Walls tight, smooth, cleanable 1		
Ceilings smooth, tight, cleanable 1		
Drainage 2		
Floors ½		
Sewer or septic tank 1		
Provision for light 2		
(10 per cent of floor space.)		
Provision for pure air 2		
Screens 1		
Minimum of shafting, pulleys, hangers, exposed pipes, etc. 1		
APPARATUS	15	
Boiler 2		
(Water heater, 1.)		
Appliances for cleansing utensils and bottles 2		
Sterilizers for bottles, etc. 2		
Bottling machine 1		
Capping machine 1		
Wash bowl, soap, and towel in handling room 1		
Condition 6		
Milk-handling machinery 3		
Pipes, couplings, and pumps 2		
Cans 1		
LABORATORY AND EQUIPMENT	2	
WATER SUPPLY	2	
Clean and fresh 1		
Convenient and abundant 1		
Total	40	

METHODS	SCORE	
	Perfect	Allowed
BUILDING	14	
Cleanliness:		
Floors 3		
Walls 2		
Ceilings 2		
Doors and windows 1		
Shafting, pulleys, pipes, etc. 1		
Freedom from odors 2		
Freedom from flies 3		
APPARATUS	7	
Cleanliness:		
Thoroughly washed and rinsed 3		
Milk-handling machinery 2		
Pipes, cans, etc. 1		
Sterilized with live steam 3		
Milk-handling machinery 2		
Pipes, cans, etc. 1		
Protected from contamination 1		
BOTTLES	7	
Thoroughly washed and rinsed 3		
Sterilized with steam 15 minutes 3		
Inverted in clean place 1		
HANDLING MILK	22	
Received below 50° F. 3		
(50° to 55°, 2.)		
(55° to 60°, 1.)		
Rapidity in handling 2		
Freedom from undue exposure to air 2		
Cooling 5		
Promptness 2		
Below 45° F. 3		
(45° to 50°, 1.)		
Capping bottles by machine 2		
Bottle top protected by cover 1		
Storage; below 45° F. 4		
(45° to 50°, 3; 50° to 55°, 1.)		
Protection during delivery 2		
(Iced in summer.)		
Bottle caps sterilized 1		
INSPECTION	6	
Bacteriological work 3		
Inspection of dairies supplying milk 3		
(2 times a yr., 2; once a yr., 1)		
MISCELLANEOUS	4	
Cleanliness of attendants 2		
(Personal cleanliness, 1; clean, washable clothing, 1.)		
Cleanliness of delivery outfit 2		
Total	60	

Score for equipment ____ plus score for methods ____ equals TOTAL SCORE ____

NOTE.—If the conditions in any particular are so exceptionally bad as to be inadequately expressed by a score of "0" the inspector can make a deduction from the total score.

FIG. 21a. Obverse Side of Score Card Used in Judging City Milk Plants.

Milk plants usually come under the jurisdiction of the city board of health and many of these have score cards of their own or if they have no score card they have blank forms on which certain essential data are recorded and which answer the purpose of a score card. In addition to this fact the milk dealers, especially the larger ones, have, as a class, been very progressive and many of them maintain research laboratories of their own.

All of the advantages and disadvantages which apply to the dairy score card apply to the score card for city milk plants and need not be repeated here. Also the same methods which are used in applying the dairy score card should be used with the card for city milk plants.

EQUIPMENT

Buildings.—Location should be free from contaminating surroundings. A good example of this would be a smoke-stack which might constantly pour soot into the plant.

Arrangement.—Arrangement is important from two standpoints, the first of which is sanitation. It is, for example, poor arrangement to have the room where the milk is handled next to the boiler room or in close proximity to the coal supply where coal dust and ashes will get into milk. The second important feature in arrangement is economy of time and space. The different rooms should be so arranged that the milk will come in at a certain point and go through the different parts of the plant with as little handling as possible and in as short a time as possible.

The separate handling room deserves especial attention, as it is poor sanitary policy to handle milk in a place where there is a chance of its becoming contaminated from outside sources. This is one of the reasons why the sales room is separate from the rest of the plant. People who have no business in the milk plant should be kept away from the place where the milk is being handled to prevent possibility of contamination.

Construction.—The entire construction should be sound, durable, and free from all cracks and crevices where dirt and dust can lodge and where milk can enter and putrefy. The slope of the floors should be not less than one-fourth of an inch to the foot and should slope toward a drain or gutter so that the water will flow away quickly and

freely. Careful check should be made to see that all floors are waterproof. All sewers should be trapped and if a septic tank is used, it should be so covered that no odor can escape.

Provision for light.—Light is necessary to perform work properly and to make possible keeping the building clean. Deductions should be made for uneven distribution of light, and if there is not the requisite number of square feet of glass, a cut should be in proportion to the deficiency, based on 10 per cent of the floor space.

Pure air is of course necessary for the health of the employees, but poor ventilation usually means a high humidity. This dampness is not only unhealthy but it is detrimental to apparatus and to the life of the building. In a humid atmosphere utensils either do not dry off at all or else they dry very slowly and this means a very decided difficulty in keeping them sterile. Screens are necessary in keeping out flies, and flies are one of the most common means of carrying germs. Special attention should be paid to the condition of the screens and this means in addition to the condition of the wire cloth itself, the fitting of the screen to the frame of the wall. A minimum of shafting, pulleys, etc., is desirable because they offer a place for the collection of dust and dirt.

Apparatus.—All of the apparatus and utensils mentioned under this heading are necessary for doing the work in the manner in which it should be done, in order to obtain the best results. Many of them are important from the sanitary standpoint. For example, in a small plant, bottling and capping might be done by hand, but one of the ideas in having these machines is to reduce to a minimum the contact of hands with the finished product. The presence of washbowl, soap and towel in the handling room makes it easier to keep the hands clean and this counts a great deal towards sanitation. The condition of utensils is important both from an economic and sanitary standpoint. Battered utensils with cracks and crevices are difficult to clean, and leaky pumps and pipes keep a place if not in a strictly unsanitary condition, at least in an unsightly condition.

Laboratory and equipment.—The laboratory and equipment are not an absolute necessity in a milk plant and in a small plant it would be impossible to maintain one because of the expense involved. Most large milk plants consider them a necessity and while they have many advantages which will be discussed elsewhere, it is

sufficient to say that a well-equipped laboratory is educational and stands for advancement.

Water supply.—A pure and abundant water supply is absolutely essential to the dairy business. Convenience of the supply is necessary because inconvenience means that the water will not be used when it should be.

METHODS

Building.—A dirty building is a constant menace to the milk handled in it. Flies and a dirty building must be considered at the same time, for if the building is dirty and flies are present, the opportunity for transmitting germ life is increased many fold. A dirty building oftentimes is associated with bad odors, although bad odors are more apt to come from faulty drains or improperly constructed septic tanks.

Apparatus.—The apparatus must be thoroughly cleaned with washing powder and the washing powder thoroughly rinsed off and the apparatus sterilized in live steam or at least scalded in boiling water. The same is true of the milk bottles. Special mention is made of the milk bottles because of their importance in the milk industry, and because so many are used in a milk plant that their chance of contamination is great. Moreover, the milk is stored in the bottle for a long time and it is the final package in which the milk reaches the consumer. All the apparatus after washing and sterilizing should be stored in a clean dry place where there is ample protection from flies and dirt. Thoroughly drying apparatus is one of the most essential practises in preventing bacterial growth.

Handling milk.—Milk intended for market purposes should be kept cold from the time it is drawn until it is consumed. It should be handled in the plant with as great rapidity as possible and at all times everything possible should be done to protect it from contamination. Cooling should be done in a place protected from contamination. The use of a bottling and capping machine is designed to protect milk from contamination by the hands of the milk plant operators.

Inspection.—Credit should be given for both bacteriological and inspection work if they are thoroughly done, by some agency other than the plant. But more credit should be given to a plant which

goes to the expense and pains of maintaining a laboratory and inspection force of its own than to one which does not.

Miscellaneous.—Under this heading, cleanliness of attendants and delivery outfit is especially mentioned. However, anything which is not provided for on the score card and yet which affects the sanitary condition of the plant may be included under this heading. The inspector might do well to note under this heading the morale and general effort throughout the entire plant to put out as good a product as is possible.

Chapter XV

JUDGING MILK AND CREAM

Judging both the chemical and sanitary quality of milk and cream is becoming more and more important. Milk has been purchased for a long time on a basis of its chemical composition and this refers principally to its fat content. Since the sanitary quality of milk and cream depends to a large extent on the bacteria content, it becomes necessary to analyze both milk and cream quantitatively for microörganisms. In some instances the price paid for the milk depends on its germ content, premiums being offered for milk below a certain germ content per c.c. If a low bacteria count is one of the prerequisites of market milk, it is only fair and logical that milk should be paid for on a basis of the number of microörganisms in it.

The ideas of the general public in regard to the quality of milk are somewhat vague. Three factors are generally used by the consumer as an index of the quality of milk. These are: (1) sediment, (2) presence or absence of the cream line, and (3) the length of time the milk will keep without souring. It must be admitted that these three factors are important in judging milk quality, although there are times when they may not indicate the true value of milk.

To enable the consumer to judge of the quality of milk, different names have been applied to various grades of milk, as, for example, the grades of A, B, and C used by the New York State Board of Health. The terms "Certified," "Baby," and "Special Milk" are terms used to indicate milk of good quality. To those having control of milk supplies these terms have a meaning, but too often they are meaningless or at least vague in their meaning to the milk-consuming public. It would be much better for both producer and dealer if the consumer knew more about grades of milk and milk quality, and for this reason those who are selling special grades of milk should be careful to keep the product up to the standard claimed for it.

It has already been pointed out that much more milk should be consumed in the diet than is now being used. This is true from the standpoint of the consumer on both a financial and dietary basis. In order to stimulate increased consumption of milk and dairy products, educational campaigns have been conducted by private companies, different dairy organizations, the dairy departments of agricultural colleges, and by the Bureau of Dairying of the United States Department of Agriculture. One of the factors which has had quite far-reaching success has been dairy products judging contests held at dairy expositions and at state and county fairs. In these contests the products are previously scored by experts and the contestant who comes nearest the score placed upon the product by the experts is the winner of the competition.

In order to make such a contest as educational as possible score cards for judging dairy products have been devised. The principle on which these score cards are used is the same as that involved in using the dairy score card, which has already been explained. Score cards for judging milk and cream are given in the following pages.

JUDGING MILK FOR BACTERIA

On the score card for judging milk, it will be noticed that a perfect score for bacteria carries a credit of 35 points. The sanitary condition of milk is the most important feature in regard to its usefulness as a food, and the number of bacteria in milk is the best and most important index of the sanitary quality of milk. On the reverse side of the score card are given various scores which should be allowed if the bacteria content of the milk falls within certain limits. The higher the bacterial count the lower the score allotted to the sample. This gradual lowering in the score of milk as the bacteria increase is in recognition of the fact that it is impossible to state the exact point at which good milk leaves off and poor milk begins. Milk may contain less than 500 bacteria per c.c. and still be rated as perfect. This allowance is made because freshly drawn milk contains a few organisms which got into it in the udder of the cow. In some instances a rough classification of the organisms found is made, such as "acid types," "rapid liquefiers," "slow liquefiers" and "putrefactive types." Usually, however, no attempt at classification is made.

SCORE CARD FOR MILK

Place.....

Class..... *Exhibit No.*.....

ITEM	PERFECT SCORE	SCORE ALLOWED	REMARKS
Bacteria	35		Bacteria found per cubic centimeter
Flavor and odor	25		Cowy, Bitter, Feed, Flat, Strong
Visible dirt	10		
Fat	10		Per cent found
Solids not fat	10		Per cent found
Acidity	5		Per cent found
Bottle and cap	5		Cap Bottle
Total	100		

Exhibitor,.....

Address,.....

(*Signed*).....

Judge

Date.....*19*

FIG. 22. Obverse Side of Score Card for Judging Milk.

DIRECTIONS FOR SCORING

Bacteria per Cubic Centimeter—Perfect Score, 35

	Points		Points
Under 500	35	25,001 to 30,000	29.0
500 to 1,000	34.9	30,001 to 35,000	28.0
1,001 to 1,500	34.8	35,001 to 40,000	27.0
1,501 to 2,000	34.7	40,001 to 45,000	26.0
2,001 to 2,500	34.6	45,001 to 50,000	25.0
2,501 to 3,000	34.5	50,001 to 55,000	24.0
3,001 to 3,500	34.4	55,001 to 60,000	23.0
3,501 to 4,000	34.3	60,001 to 65,000	22.0
4,001 to 5,000	34.0	65,001 to 70,000	21.0
5,001 to 6,000	33.8	70,001 to 75,000	20.0
6,001 to 7,000	33.6	75,001 to 80,000	19.0
7,001 to 8,000	33.4	80,001 to 85,000	18.0
8,001 to 9,000	33.2	85,001 to 90,000	17.0
9,001 to 10,000	33.0	90,001 to 95,000	16.0
10,001 to 11,000	32.8	95,001 to 100,000	15.0
11,001 to 12,000	32.6	100,001 to 120,000	12.5
12,001 to 13,000	32.4	120,001 to 140,000	10.0
13,001 to 14,000	32.2	140,001 to 160,000	7.5
14,001 to 15,000	32.0	160,001 to 180,000	5.0
15,001 to 20,000	31.0	180,001 to 200,000	2.5
20,001 to 25,000	30.0	Above 200,000	0.0

Note.—When the number of bacteria per cubic centimeter exceeds the local legal limit the score shall be 0.

Flavor and Odor—Perfect Score, 25

Deductions for disagreeable or foreign odor or flavor should be made according to conditions found. When possible to recognize the cause of the difficulty it should be described under Remarks.

Visible Dirt—Perfect Score, 10

Examination for visible dirt should be made only after the milk has stood for some time undisturbed in any way. Raise the bottle carefully in its natural, upright position, without tipping, until higher than the head. Observe the bottom of the milk with the naked eye or by the aid of a reading glass. The presence of the slightest movable speck makes a perfect score impossible. Further deductions should be made accord-

DIRECTIONS FOR SCORING—*Continued*

ing to the amount of dirt found. When possible the nature of the dirt should be described under Remarks.

FAT IN MILK—PERFECT SCORE, 10

	Points		Points
4.0 per cent and over...	10	3.2 per cent.....	6
3.9 per cent.....	9.8	3.1 per cent.....	5
3.8 per cent.....	9.6	3.0 per cent.....	4
3.7 per cent.....	9.4	2.9 per cent.....	3
3.6 per cent.....	9.2	2.8 per cent.....	2
3.5 per cent.....	9	2.7 per cent.....	1
3.4 per cent.....	8	Less than 2.7 per cent..	0
3.3 per cent.....	7		

Note.—When the per cent of fat is less than the local legal limit the score shall be 0.

SOLIDS NOT FAT—PERFECT SCORE, 10

	Points		Points
8.7 per cent and over...	10	8.1 per cent.....	4
8.6 per cent.....	9	8.0 per cent.....	3
8.5 per cent.....	8	7.9 per cent.....	2
8.4 per cent.....	7	7.8 per cent.....	1
8.3 per cent.....	6	Less than 7.8 per cent..	0
8.2 per cent.....	5		

Note.—When the per cent of solids not fat is less than the local legal limit the score shall be 0.

ACIDITY—PERFECT SCORE, 5

	Points		Points
0.2 per cent and less...	5	0.23 per cent.....	2
0.21 per cent.....	4	0.24 per cent.....	1
0.22 per cent.....	3	Over 0.24 per cent.....	0

BOTTLE AND CAP—PERFECT SCORE, 5

Bottles should be made of clear glass and free from attached metal parts. Caps should be sealed in their place with hot paraffin, or both cap and top of bottle covered with parchment paper or other protection against water and dirt. Deduct for tinted glass, attached metal parts, unprotected or leaky caps, partially filled bottles, or other conditions permitting contamination of milk or detracting from the appearance of the package.

FIG. 22a. Reverse Side of Score Card for Judging Milk.

SCORE CARD FOR CREAM.

*Class*_____ *Exhibit No.*_____

ITEM.	PERFECT SCORE	SCORE ALLOWED	REMARKS.
Bacteria	35		Bacteria found per cubic centimeter
Flavor and odor	25		Flavor Odor
Visible dirt	10		
Fat	20		Per cent found
Acidity	5		Per cent found
Bottle and cap	5		Cap Bottle
Total	100		

Exhibitor, _____

Address, _____

(*Signed*) _____
Judge

Date, _____ *19*

FIG. 23. Obverse Side of Score Card for Judging Cream.

EXPLANATION OF SCORES

BACTERIA PER CUBIC CENTIMETER—PERFECT SCORE, 35.

	Points
Less than 400	35
400 and less than 700	34.5
700 and less than 1,000	34
1,000 and less than 2,000	33.5
2,000 and less than 3,000	33
3,000 and less than 4,000	32.5
4,000 and less than 5,000	32
5,000 and less than 6,000	31.5
6,000 and less than 7,000	31
7,000 and less than 8,000	30.5
8,000 and less than 9,000	30
9,000 and less than 10,000	29
10,000 and less than 15,000	28
15,000 and less than 20,000	27
20,000 and less than 25,000	26
25,000 and less than 30,000	25
30,000 and less than 35,000	24
35,000 and less than 40,000	23
40,000 and less than 45,000	22
45,000 and less than 50,000	21
50,000 and less than 55,000	20
55,000 and less than 60,000	19
60,000 and less than 65,000	18
65,000 and less than 70,000	17
70,000 and less than 75,000	16
75,000 and less than 80,000	15
80,000 and less than 85,000	14
85,000 and less than 90,000	13
90,000 and less than 95,000	12
95,000 and less than 100,000	11
100,000 and less than 110,000	10
110,000 and less than 120,000	9
120,000 and less than 130,000	8
130,000 and less than 140,000	7
140,000 and less than 150,000	6
150,000 and less than 160,000	5
160,000 and less than 170,000	4
170,000 and less than 180,000	3
180,000 and less than 190,000	2
190,000 and less than 200,000	1
200,000 and over	0

FLAVOR AND ODOR, PERFECT SCORE, 25.

Deductions for disagreeable or foreign odor or flavor are made according to conditions found. When possible to recognize the cause of the difficulty it is described under Remarks.

VISIBLE DIRT—PERFECT SCORE, 10.

Examination for visible dirt is made only after the milk has stood for some time undisturbed in any way. Raise the bottle carefully in its natural, upright position, without tipping, until higher than the head. Observe the bottom of the milk with the naked eye or by the aid of a reading glass. The presence of the slightest movable speck makes a perfect score impossible. Further deductions are made according to the amount of dirt found. When possible the nature of the dirt is described under Remarks.

FAT IN CREAM—PERFECT SCORE, 20.

If 20 per cent fat or above, score perfect. Deduct 1 point for each one-half per cent fat below 20.

ACIDITY—PERFECT SCORE, 5.

	Points
0.2 per cent or less	5
0.21 per cent or over 0.20	4
0.22 per cent or over 0.21	3
0.23 per cent or over 0.22	2
0.24 per cent or over 0.23	1
Over 0.24 per cent	0

BOTTLE AND CAP—PERFECT SCORE, 5.

Bottles should be made of clear glass and free from attached metal parts. Caps should be sealed in their place with hot paraffin, or both cap and top of bottle covered with parchment paper or other protection against water and dirt. Deduotions are made for tinted glass, attached metal parts, unprotected or leaky caps, partially filled bottles, or other conditions permitting contamination of milk or detracting from the appearance of the package.

FIG. 23a. Reverse Side of Score Card for Judging Cream.

JUDGING MILK FOR FLAVOR AND ODOR

The flavor and odor are placed next to bacteria in importance, because it is largely by these two characteristics of milk by which the consumer judges the commercial value of the product. If the flavor and odor are abnormal, the customer will not purchase the milk. In placing a score on the flavor and odor of milk judgment is frequently based as fine as one-half a point. To those who have never tried to judge of the flavor and odor of milk on a numerical basis, such fine distinctions might seem almost impossible. It is, however, surprising to what a high degree of accuracy the senses of taste and smell may be trained by practise.

In judging the flavor and odor of milk it is best to taste of several samples of both good-flavored and bad-flavored milk before commencing to place a numerical score on any of them. Tasting of these extremes in flavor helps the judge to standardize his taste and to place a more equitable score on samples which come between these extremes. In any important milk and cream contest it is best to have three judges in order to get a variety of opinion over any disputed points. It is a fact that in rare instances a certain judge of milk and cream will be unable to detect an undesirable flavor or odor which is perfectly apparent to others. Milk and cream should always be warmed to a temperature a little above that of body temperature before being judged. Low temperatures will nearly always disguise bad flavors and odors. It is also important to rinse out the mouth with water before tasting a succeeding sample. The bad flavor of a sample of milk may easily be carried in the mouth to the succeeding sample, thus making probable the rendering of an unfair decision.

It is always well, if possible, to designate the kind of flavor and odor responsible for cuts made in judging milk. Suggestions for naming some of the objectionable flavors and odors are made on the score card. It is, however, very difficult to designate the causes of flavors and odors in milk. Many of them are supposed to be due to the action of bacteria but very little work has been done on this important subject to show that this is the case.

JUDGING MILK FOR VISIBLE DIRT

There is no excuse for milk containing much visible dirt as proper straining will remove nearly all foreign matter. Much of the dirt present in milk is of a specific gravity only a little greater than the milk itself. For this reason it is easily forced into suspension. A

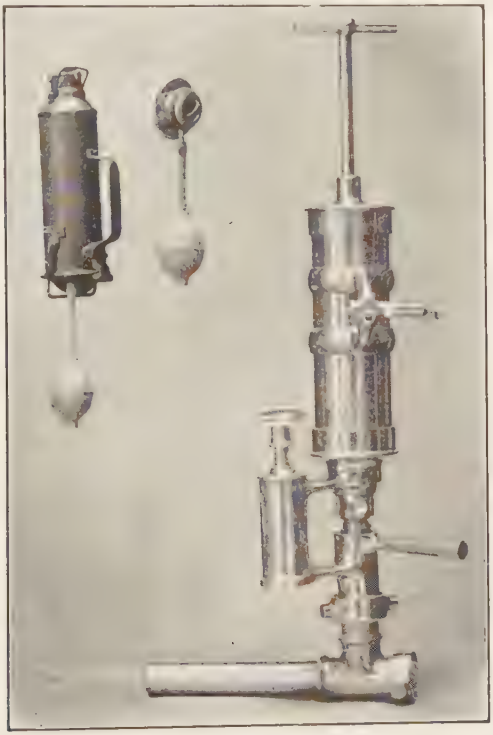


FIG. 24. Three Types of Milk Sediment Testers.

bottle of milk should stand for an hour before being judged in order to let all dirt settle to the bottom of the bottle. The bottle should then be raised gently so that the bottom of the bottle is above the eye, care being taken to keep the bottle in a vertical position so that the sediment will not be driven into suspension. The bottom of the bottle should be wiped with a clean cloth so that any specks of dirt located there will not be confused with sediment which may be in the

milk. It is a good plan to examine the milk with a magnifying glass as oftentimes dirt invisible to the naked eye will be revealed. In placing a score for visible dirt, it is sometimes necessary to judge as fine as .2 of a point; and sometimes the character of the dirt as well as the amount is taken into account. Another method of judging the visible dirt is to filter the milk through cotton discs which are made for the purpose.

Dirt in milk is always objectionable as it is liable to be a carrier of disease producing organisms. It also offends the æsthetic sense of the consumer and it denotes carelessness at some point in the production or handling of milk. However, there is not necessarily any direct relation between the amount of dirt in milk and the numbers of bacteria per c.c. This is shown by the following table.[98]

Table 67.—Comparison Between Visible Dirt and Bacteria in Milk.

Date	Pounds Milk	Milligrams Dirt	Bacteria per c.c.
Feb. 24 a.m.	162.1	487.3	12,734
Feb. 24 p.m.	148.1	986.8	8,416
Feb. 25 a.m.	167.7	584.6	12,400
Feb. 25 p.m.	148.9	448.6	12,115
Feb. 26 a.m.	161.1	596.5	17,896
Feb. 29 p.m.	142.1	503.9	14,800
Mar. 1 a.m.	158.7	518.1	19,577

It can be seen by referring to this table that there is not necessarily any direct relation between amount of dirt in milk and the numbers of bacteria present. In fact, in this particular case, the sample having the greatest number of m.g. of dirt (Feb. 24 P.M.) had by far the smallest number of bacteria per c.c. This may have been the case for two reasons. The dirt may have been comparatively free from bacteria when it entered the milk, or the bacteria had not yet had time to develop. This latter reason is often the cause of dirty milk having a small number of germs per c.c., and is very misleading. A sample of milk containing considerable quantities of visible dirt and having only 10,000 bacteria per c.c. would not be considered as having a high bacteria count, yet if the milk were fresh, the count would be high from the standpoint of initial contamination. If the milk was subjected to any unfavorable con-

[98] Harding, H. A., Prucha, M. J. Germ Content of Milk as Influenced by Visible Dirt. Ill. Sta. Bull. No. 236.

ditions, e.g., high temperatures, this high initial count would multiply to such an extent that the milk would soon contain countless numbers of organisms.

FAT AND SOLIDS NOT FAT

In judging the fat and solids not fat of milk a value is placed on the milk as a food. The fat is usually determined by the Babcock test and the solids not fat are usually calculated by some formula using the fat reading and the lactometer reading. On the reverse side of the score card are suggested deductions which should be made if the percentage of fat and the percentage of solids not fat fall below certain standards. If the percentage of fat falls below 2.7 per cent or the solids not fat fall below 7.8 per cent, the sample should be given zero. This is true, even if the milk is known to be normal, for there is no excuse for putting on the market milk which is so low in food value. It should be noted that the food value of milk is given a possible 20 per cent of the entire value allotted to milk on the score card.

ACIDITY

The acidity of milk is determined by titrating a given weight of the milk with a standard alkali solution. Definite cuts are made in the score if the acidity is above 0.2 per cent. In a milk contest the highest acidity of any of the samples in the competition is sometimes taken as a standard, providing the acidity of this sample is below 0.2 per cent. Cuts are then made on the same basis as when the standard was 0.2 per cent.

To any one not familiar with judging milk, a value of only 5 per cent allotted to acidity may seem rather low. However, since the scoring of milk is due to bacterial action any appreciable increase in acidity above that which is normal will always be accompanied by a large increase in bacteria. Bacteria receives the largest percentage recognition of any other point on the score card and, since, in the case of milk containing abnormal amounts of acid the bacteria count would receive a low rating, it is not necessary to make another cut for acidity in order to place the sample of milk in a low class where it belongs. This gives an opportunity to give a higher percentage value to some other important points on the score card

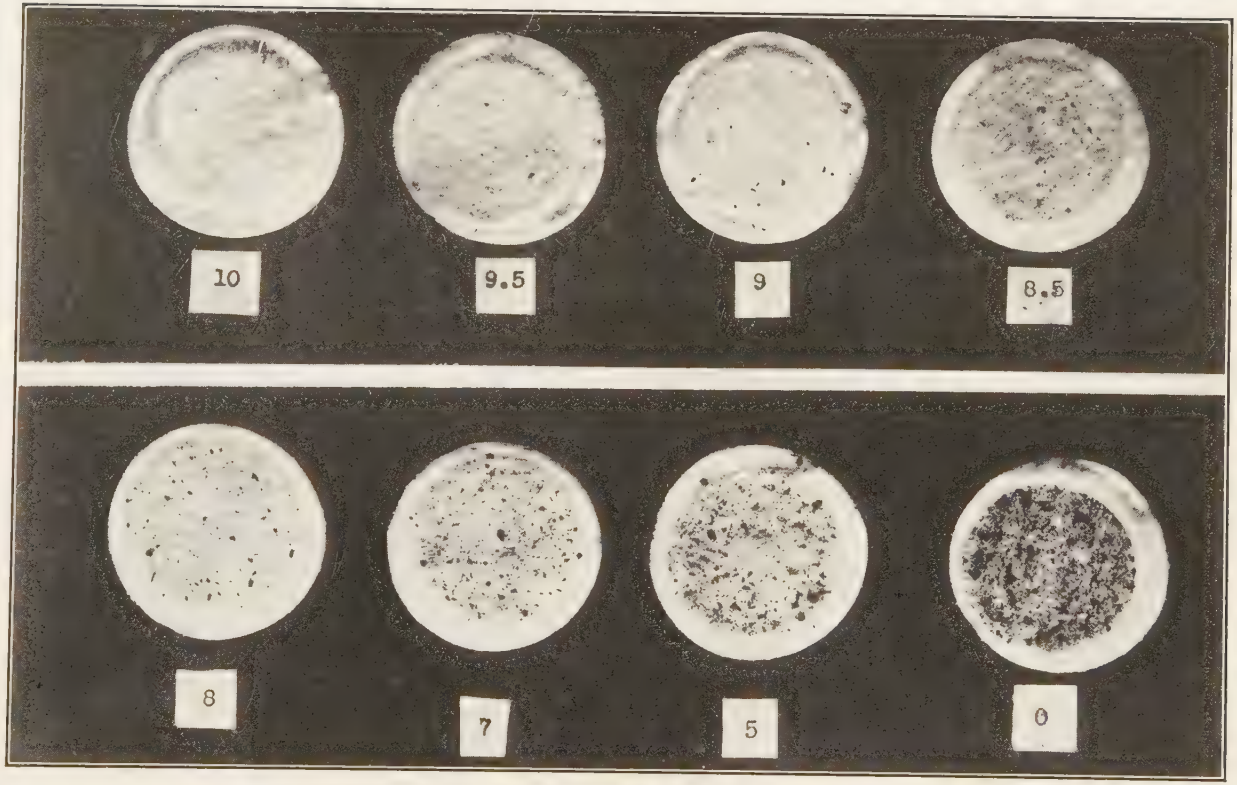


FIG. 25. Filters Obtained From Milk Containing Different Amounts of Dirt. Note Scores Assigned to Different Amounts Of Sediment.

without essentially lowering the emphasis placed on milk high in acidity. If the acidity of the milk is so high that it is distinctly sour to the taste, the sample should be excluded and given zero on all points as it could not be sold in the open market.

BOTTLE AND CAP

The bottle and cap are indicative of the care and pride which a dairyman takes in putting milk on the market. The bottles should be clean and of clear glass and special pains should be taken to note whether there are any cloudy spots on the inside of the bottle. It sometimes happens in the cases of bottles not properly rinsed that washing powder and perhaps some sediment from the wash

FIG. 26. Milk Bottles Capped in Different Ways. Beginning at the Left They Are Named as Follows: Standard; Jam Perfecto; Crown; Ordinary Cap.

water will adhere to the inside of the bottle, and if the bottle is sterilized in live steam this will bake on the inside. The bottles should be examined to see that they are not chipped on the edge as these edges may be very sharp, and also be deep enough to allow the milk to leak out.

The ordinary pasteboard cap allows dust and dirt to collect on the top and on the edge of the bottle, and this dirt may easily be

rinsed off into a glass or other container when the milk is poured from the bottle. If the milk in the bottle warms up, it is sure to leak out around the edge of the cap and this makes ideal conditions for the multiplication of bacteria. Special caps covering the entire top of the bottle have been devised, but these cost more than the ordinary cap and unless the dealer receives an extra price for his milk, he cannot afford to use caps of this sort. In some cases a piece of parchment paper held in place by a rubber band has been used to cover the top of the bottle, and while such a protection is better than nothing, it will not stand very rough usage.

In judging milk it is customary to give a cut of one point in cases where only the ordinary cap is used. Other caps are given credit according to their merits, and any cap is given full credit if it covers the entire top of the bottle and is durable enough to stand ordinary rough usage, such as icing, and is practical to use in market milk work.

At the time that the bottle and cap are judged, the fact should be noted as to whether or not the bottle is full, and a cut made in proportion to the amount which is lacking.

THE SCORE CARD FOR JUDGING CREAM

The score card used for judging cream is almost the same as the one for judging milk. The main difference in the two cards lies in the fact that the item of "solids not fat" is removed from the cream score card, and the extra 10 points are added to the value allowed to the fat content. This is done because the fat is the chief solid desired by the customer when he purchases cream.

Cream is a good example of a concentrated and valuable commodity offered for sale in a small volume. For this reason great attention should be paid to the fact as to whether or not the bottle is full and a much more severe cut is given in the case of cream to a bottle which is not full than is given in the case of milk.

The flavor of cream is very different from that of milk and this difference is due to the high fat content. On this account milk and cream should be judged separately. If one has been judging milk, it is best to taste of several samples of cream before placing a judg-

ment on any of them in order to become perfectly familiar with the taste due to a high fat content.

With these few exceptions above mentioned, the directions given for the judging of milk will apply to cream.

Chapter XVI

DAIRY BUILDINGS, DAIRY BARN AND MILK HOUSE

The construction and arrangement of the dairy barn is very important in clean milk production. In building a new barn it is easy to use the proper construction, but in remodeling an old barn, for sanitary and economic reasons, great difficulty is sometimes experienced in installing sanitary measures and appliances.

Location.—The first thing to consider in building a dairy barn is the location. It should stand preferably on a soil which has natural drainage, such as sand or gravel, and it should never stand in a hollow where all of the moisture would naturally flow toward the building. If it is necessary to erect a barn on a heavy clay soil, it is a good plan to underdrain the site with tile, as this will do much in removing excess moisture. Dampness in any building is always to be avoided; and the building should always be provided with eve troughs to carry off rain water. Otherwise, the rain from the roof must fall where more or less of it would flow under the barn, causing a great deal of dampness—a condition not only harmful to the animals housed in the building, but to the building itself.

Locating a dairy barn near a constant source of contamination should be avoided, and in this would be included hen houses, pig sties, ponds of stagnant water, cess pools and privies. Nearness to a dusty road is also to be avoided if possible, as dust-laden air may cause a great deal of contamination. The barn should also be located where it is convenient to the other buildings with which the work carried on in it is more or less associated, and it should be easily accessible to a team and wagon, especially if the manure is to be loaded directly into a wagon or manure spreader.

In northern regions it is best for a dairy barn to face the south if possible, as this tends to make the barn warmer, and a barn so located will get better light, especially in winter. Sometimes it is possible to protect the barnyard on the east and west with other

FIG. 37. Unsanitary Conditions in a Cow Stable. Note Hay Hanging from Ceiling and Horse Kept in Stable With Cows.

farm buildings which helps to keep cold winds from blowing directly against the stable.

Barns may be roughly divided into two classes:

1. Surface barns, those built entirely above the surface of the ground; and

2. Basement barns, those built on a slope of ground and having at least one side against a bank of earth. Frequently a basement barn has a bank of earth on more than one side of the stable.

Basement barns have the following disadvantages:

1. They are liable to be dark.
2. They are liable to be damp.
3. They are liable to be poorly ventilated.

They have the following advantages:

1. They are warm so far as protection from winds is corncerned.
2. Much space is confined under one roof. This makes them convenient and economic of construction.

The fact that basement barns are apt to be poorly lighted and poorly ventilated is greatly in their disfavor. However, in some instances it is possible to light and ventilate them fairly well. The economic side of constructing a basement barn cannot be entirely overlooked, and if the objectionable features can, to a fair degree, be overcome, the basement barn should not be unconditionally condemned.

Walls.—The barn should always be provided with a good wall, and the building should be raised far enough above the surface, so that dust and dirt will not work into the stable. Furthermore, it is detrimental to the life of the building to have it resting on the ground. Where this occurs the sills must be renewed frequently because moisture soon rots them.

A good stable wall should meet the following requirements:

1. It should be durable.
2. It should be warm.
3. It should be economical to construct.
4. It should have a smooth surface so that dirt will not stick to it and so it can be readily cleaned.
5. It should be impervious to moisture.

FIG. 28. Exterior View of Inexpensive Barn, in Which, by Good Methods, Milk of Consistently Low Bacterial Content Was Produced.

It is needless to say that no one material is ideal from the standpoint of these requirements. A great many materials have been used for wall construction, among which are wood, brick, hollow tile, stone and concrete. All of these materials have some advantages and some disadvantages, but probably the two kinds of walls most in use at the present time are concrete, and stone laid up in cement. The stone and cement wall is durable and economical in construction. It is of course rough and if it forms a part of the stable wall, as in a basement barn, it should be covered on the inside with a coating of cement to make the wall smooth so that dust will not readily stick to it. This coating also helps to prevent the passage of air through the wall. Concrete walls are being used more and more in barn construction, since they are easy to build, are comparatively economical in construction, and are very durable. Both stone and cement, and concrete walls allow to some extent the passage of moisture through them; but a point in favor of the cement wall is it can be waterproofed quite easily. Different concerns manufacture waterproofing materials for this purpose.

Floor.—The stable floor should meet the following general requirements:

1. It should be durable.
2. It should be economical to construct.
3. It should be simple in construction.
4. It should be impervious to moisture.
5. It should be smooth enough to be easily cleaned.
6. It should be rough enough to prevent slipping.
7. It should be level where the animal stands. A sloping floor is liable to weaken the backs of the animals.

Of course, no one floor is ideal and nearly all possible materials have been tried. Dirt floors are not suitable for a dairy barn as they cannot be kept clean and are cold and damp. They may, however, be used successfully with fat stock, if a sufficient supply of bedding is used. Brick soon wears out and it is quite difficult to fill in between the bricks and get a smooth, clean finish with no cracks or crevices where dirt and manure can lodge. If bricks are used for flooring it is recommended that cement be dusted in the cracks with a broom and then the floor sprinkled and the cement left to harden.

Cork bricks have been used for stable floors but have never come into common use.

Plank floors of hard lumber, such as oak, have been used longer than any other type of floor and they are fairly satisfactory. It is difficult, however, to keep them clean and with the best of efforts they will in time become saturated with liquid manure. This in time causes them to rot and necessitates their replacement. Probably one reason why plank floors have been so universally used has been because of the availability of lumber and its comparative cheapness, and the ease with which the floor could be replaced.

At the present time, with the scarcity and the consequent high price of lumber, it is doubtful if the plank floor is as economical as a cement floor. The cement floor probably comes nearest to being the ideal floor for a cow stable than any other type of floor. It is objectionable in several ways, one of which is its hardness, but this objection may be overcome by using a moderate amount of bedding. A cement floor is also apt to be damp and consequently cold. A large part of this trouble may be overcome in the use of waterproofing material, already mentioned for wall construction.

A cement floor is much superior to a wooden floor, so far as ease of cleaning is concerned, and this is especially true if the floors are scrubbed with water as is done in the dairies producing high grade milk. Cement construction is also superior when it becomes necessary to disinfect the stables after any occurrence of an infectious, contagious disease.

The dimensions of different parts of the stable are important in keeping the stable clean and also from the standpoint of the health of the animal. The score card calls for a minimum of 500 cubic feet of air space per cow. Sometimes in order to obtain this amount of air the walls of the stable are extended in height. It is best to build stable walls not much over 8 feet high as otherwise the stables are apt to be cold. Warm air rises and if the stables are built with excessively high ceilings the warm air will rise to the top of the room, leaving cold air surrounding the animals. The space back of the animals—from the edge of the gutter to the wall—should be wide enough to allow free passage of the animals and to prevent the manure from spattering on the wall. This space behind the animals should be not less than 4 feet and 5 feet would be more satisfactory.

The exact size of the manure gutter is not so important except that it should be large enough to hold all of the solid and liquid manure. It should not be so deep that if a cow should happen to step into it, she would be in danger of falling, and it should be wide enough to accommodate the ordinary barn shovel. A manure gutter 16 inches wide and 10 inches deep is frequently recommended.

Stalls.—The bench on which the cow stands should be just long enough for the animal to stand on it and allow the droppings to fall into the gutter. If the bench is too long the droppings fall onto it, which tends to keep the cow in a filthy condition; if the bench is too short, the animal stands with her hind feet in the gutter.

In building a barn it is, therefore, quite essential to keep in mind the breed of cattle to be housed. With a mixed herd, it is impossible to build a stable that will be of the right size for all members of the herd. The length of the stall, where the cow stands, usually varies from 4 feet 6 inches to 5 feet, depending on the size of the animals kept. These dimensions include the distance from the sill of the manger to the edge of the gutter. In case the bench where the animal stands is too long, a false floor 2 or 3 inches thick is sometimes laid on the main floor, and this gives a shallow manure gutter directly behind the animal. Sometimes a wooden floor is laid over a cement floor because the latter is hard and cold. From a sanitary standpoint the use of these false floors is to be discouraged. They do not fit tightly to the cement floor and the liquid manure works under them, causing a very unsanitary condition. For relieving the hardness and coldness of the cement floor, it is better to use bedding than to construct a wooden floor over a cement floor.

The width of cow stalls, like the length, will vary with the size of the animals kept. They usually vary from 3 feet to 3 feet 8 inches. The value of a partition between the cows is a much disputed question, there being two factors against its use: (1) It adds to the expense of construction, and (2) cows in lying down very frequently injure themselves by striking a hip against the partition.

The main factor in favor of partitions between cows is in preventing a cow that is standing from stepping on the udder of a cow next to her who is lying down. Partitions are sometimes of wooden construction, but frequently they are built of iron pipe, the latter being preferable because of the ease of keeping them clean.

Stanchions.—There are two main types of stanchions—the rigid, and swing types, and in each one there are variations in ways of construction. The swing type is better than the rigid because it contributes to the comfort of the cow. Many stanchions are constructed of iron instead of wood and these are usually preferred because they are generally easier to keep clean than those made of wood.

Mangers.—Mangers are of two main types, the box manger and the continuous floor manger. Mangers of any type should be built without crevices to prevent feed getting into them and souring. Since mangers are quite difficult to clean the tendency has been to construct them in a simple manner to make cleaning as easy as possible. The floor manger is the outgrowth of this idea. The space in front of the stanchions which is used as a passageway is raised 6 inches or 8 inches above the floor level and a depression is made in this space with a slope toward the stanchion. The use of the floor manger was further encouraged by using it for a watering trough also. An inlet water pipe was introduced at one end and a drain at the other with a slight slope toward the drain. When water was turned on, it therefore flowed in front of all the cattle and made it possible to wash the manger with a minimum of labor. Many veterinarians claim that the floor manger has done much to spread tuberculosis in herds and this is especially true where the manger was used as a watering trough. If an animal at one end of the line is giving off tuberculosis germs in her sputum, these are distributed along the entire length of the manger. These floor mangers are quite shallow with no protection in front so that the animals throw their feed out into the alleyway. This necessitates the sweeping of the feed back into the mangers two or three times during each feeding. The best type of mangers are constructed of cement, being about 15 inches to 18 inches wide at the bottom and sloping very slightly toward the animal. There should be partitions between each animal to prevent an interchange of feed and thus avoid the spread of tuberculosis from one animal to another. The front wall of the manger need not be over 12 inches high, and if it flares away from the animal, it lets in more light and allows better circulation of air. All corners should be filled with cement to prevent accumulation of feed in them. If wooden construction is used

instead of cement half round moldings can be fastened in the corners to keep the feed out of them.

Many dairymen are in favor of drinking cups for cows, and claim that the constant supply of drinking water increases the milk yield. Where drinking cups are installed they should be provided with drainage; otherwise they fill up with feed, causing an unsanitary condition. It is best to provide individual cups for each cow instead of one cup for two cows as is frequently done to lessen expense of installation. One cup for two cows increases the danger of the spread of tuberculosis, although there is not as much danger from this source as where cows are watered with water running along a floor manger.

When two rows of stanchions are installed in a cow barn, the

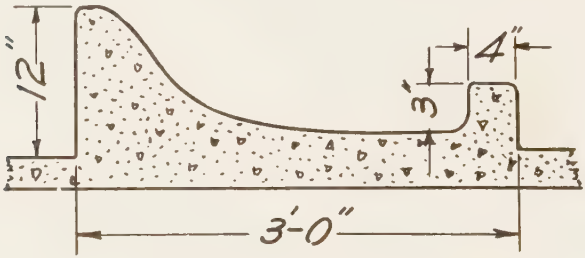


FIG. 29. Cross-Section Detail of Cement Manger.

question often arises as to whether the cows should face in or face out. So far as can be determined it makes no difference which way the cows face; the matter is one of individual preference on the part of the dairyman. In one case all of the manure is handled from one alleyway, and in the other case all of the feed from another alleyway. In barns built with the intention of loading the manure directly into a wagon the cows face outward. The driveway in this case would have to be not less than 8 feet wide.

Light.—Light is necessary for two reasons: (1) The proper performance of the work, and (2) keeping the building clean. In keeping a building clean the factor of light has a double significance. It is practically impossible to keep a building clean unless every part of it can be easily seen, and if there are dark corners, those places will nearly always be found to contain more or less dirt. In the

second place, light to quite an extent acts as a germicide since most bacteria do not grow well in a strong light, particularly sunlight. The score card calls for not less than 4 square feet of glass per cow. It is important that this light be not only adequate, but evenly distributed. It is of course possible to get so large a number of square feet of glass per cow that the barn will be cold, but this almost never occurs.

It has been stated that a dairy barn should face the south; one of the reasons given is because the most horizontal rays of light come from the south, especially in winter. It is the horizontal rays of light which strike most directly on a window, and most of the rays of light come from high up in the sky. For this reason all windows should be placed in a building with their length perpendicular to the sill of the barn, otherwise most of the rays of light will not strike the glass but will shoot over the window. The fact that most light rays are reflected obliquely and not horizontally is one of the reasons why it is so difficult to light a basement barn. In many basement barns there is considerable space between the surface of the bank of earth and the sill of the barn, and this may allow the installation of a considerable number of square feet of glass. However, of a necessity, the longest dimension of the window must be placed parallel with the sill of the barn and so the oblique rays of light do not strike the glass but shoot over it, with the result that the stable is dark.

In order to introduce more direct rays of light into a basement two plans are adopted. One is to dig an areaway 3 or 4 feet deep, and about 3 feet wide and 4 feet long, and face this excavation with a stone or cement wall. It should also have a floor of cement. This opening makes it possible to install a fair-sized window, with its greatest length perpendicular to the sill of the barn. The greatest objection to this method of lighting is the dirt, snow and water which collect in the space. The areaway should be provided with a drain to carry off water, but in winter this is liable to freeze and so become useless. This method of providing window space always causes more or less trouble and inconvenience.

The second plan of lighting a basement is to place a window sash of any desired size in the side and above the sill of the barn. An opening is then cut in the floor of the barn the same size as the sash.

This space should then be boxed in with tight-fitting boards, so that the rays of light will be concentrated in the basement below, and also to form a guard around that portion of the floor which has been removed. If desired, a second sash can be laid over the part of the floor which has been removed, and this will prevent dust and dirt from falling into the basement from above. One objection to this method of lighting is that it removes considerable space from that part of the barn where the floor is removed.

The panes of glass in a dairy stable should not be too small as this means that an undue proportion of the space is allotted to window sash and more work must be done to keep a window clean if many small panes of glass are used than would be the case if the panes are larger. On the other hand, if the panes are too large, it is expensive to replace them if one gets broken. Panes of glass 8 inches by 10 inches usually give good satisfaction in a dairy stable.

Windows should be hinged at the bottom and let down from the top, as this arrangement makes it possible to ventilate the barn without having a draft directly on the animals. The cold air current strikes the window and is deflected upward over the bodies of the animals. This arrangement of the window is also more sanitary than if the window were installed as is ordinarily the case, or if it is hinged like a door. Dust and dirt do not blow directly into the stable but like the air currents are deflected upwards and some lodge on the windows and do not enter the stable at all. In order to insure that the current of air will be deflected upward when the window is open, strips of wood or galvanized iron are sometimes placed at the sides of the window sash in such a way that the sash and the strips form a tight compartment with the opening at the top. This prevents air currents around the sides of the window sash.

Ventilation.—The question of ventilation is a very important one. Way,[99] who has given a great deal of thought and study to this feature of barn sanitation, is of the opinion that it is the most important sanitary feature in the equipment of a dairy barn. In an experiment performed at Wisconsin[100] a group of cows was kept under certain conditions with good ventilation. They were then kept under the same conditions except the ventilating conditions were

[99] Way, Cassius, The Sanitary Barn and Clean Milk Production, 16th Annual Report of the United States Live Stock Sanitary Association.

[100] Wisconsin Exp. Sta. Report 1891.

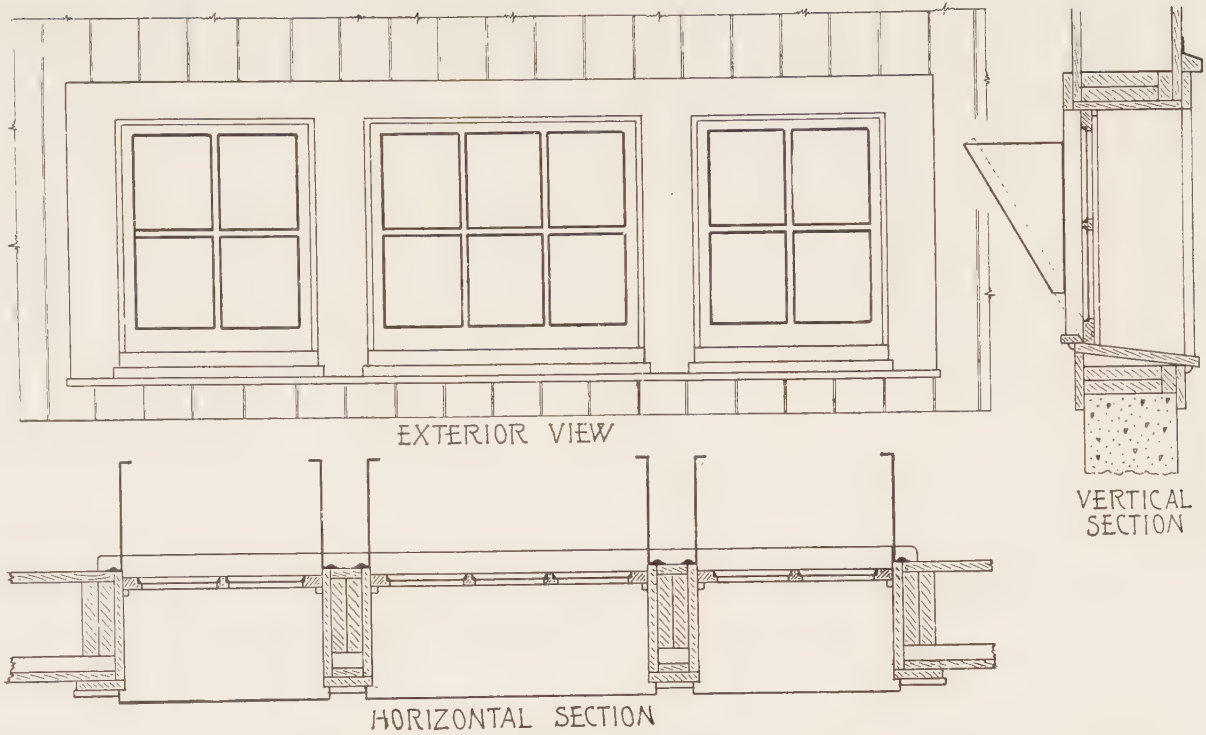


FIG. 30. Detail of Window Suitable for a Cow Stable.

extremely poor. The cows gave less milk when kept under conditions with poor ventilation and they lost in weight, the average loss being 10.75 pounds per cow.

On account of the many factors involved it is very difficult to give a good comprehensive definition of ventilation. A loose definition is that ventilation is the exchange of impure air for pure air. When animals breathe they take into the lungs oxygen, and give off carbon dioxide, which in sufficient quantities is poisonous. Our idea then of pure air is one which does not contain an excessive amount of carbon dioxide; or looking at the question from another angle, pure air would be air which does not contain any harmful substance and which contains sufficient oxygen to supply the needs of the body. However, other factors, such as humidity and heat, are almost as closely connected with ventilation as is the question of carbon dioxide and oxygen.

The amount of pure air which different animals must breathe within a given time, in order to obtain sufficient oxygen, has been determined. These amounts are given in the following table: [101]

Table 68.—Amount of Air Breathed by Different Animals.

Animal	Cu. Ft. Air Breathed per Hour	Cu. Ft. Air Breathed per 24 Hours
Horse	141.7	3401
Cow	116.8	2804
Pig	46.0	1103
Sheep	30.2	726
Man	17.7	425
Hen	1.2	29

The rate at which air must be supplied to a stable is a very perplexing question, because of the conditions which affect rate of air flow and also because of variations in temperature, which in turn influence humidity. It is desirable to keep stable air as dry as possible, and this is accomplished by passing air through the stable at a given rate under certain conditions of temperature and humidity. If the humidity of the outside air is increased before it enters the stable, its rate of flow would obviously have to be increased in order to maintain the same standard conditions of moisture in the stable.

[101] King, F. H., Ventilation for Dwellings, Rural Schools and Stables, Madison, Wisconsin. (Used by permission.)

The relative temperature of the air inside and outside of the stable has a big influence on the amount of air required per given time, to remove a desirable amount of moisture from the stable. If a cubic foot of air at 40° F. is 80 per cent saturated, and the air is warmed to 50° F., it will occupy a larger volume and so will hold more moisture. More of it would therefore be required to maintain the proper moisture conditions inside the stable when it was at 50° F. than when it had a temperature of 40° F.

At the same time that air is being supplied to regulate temperature and humidity it must also furnish a sufficient amount of oxygen. It has already been stated that the chief harmful product in impure air is carbon dioxide. It has never been exactly determined what percentage of carbon dioxide in air is harmful. The amount allowable has been variously stated at from .02 per cent to .08 per cent by volume, but many experiments seem to show that under certain conditions as high as .5 per cent by volume of carbon dioxide may be present without causing any apparent harmful effects. It seems to be the consensus of opinion that lowering the proportion of oxygen to carbon dioxide causes more harmful effects and is therefore more important in ventilation than is the presence alone of a certain percentage of carbon dioxide.

The above discussion brings out four conditions which must prevail in order to have good ventilation in any building. These conditions are (1) elimination of moisture, (2) diffusion of air, (3) control of temperature and (4) sufficient supply of oxygen. Without any one of these conditions a ventilating system is imperfect and it would be difficult to say which one is most important, as it is very difficult in actual practise to have one condition eliminated without affecting all of the others. For example, if moisture is not eliminated from the stable, it is quite apt to be true that the air is not being diffused and that a sufficient amount of air is not being supplied. The presence of an excess of moisture would increase the process of evaporation and tend to make the stable cold.

The four factors causing ventilation are (1) wind blowing across a ventilator, (2) wind pressure against a building, (3) suction of wind on the leeward side of a building, and (4) difference in temperature of air between the outside and inside of a building. Sometimes all of these factors are working at once, and again sometimes

all four factors are exerting so little influence that exchange of air between the inside and outside takes place very slowly. In all buildings there is more or less exchange of air through the walls, the rate of exchange depending largely on the construction of the walls and the wind pressure against the structure.

There are three main methods of introducing air into a stable: (1) through direct openings, (2) through some porous membrane,

FIG. 31. Neat, Attractive Dairy Barn. Note Plentiful Supply of Windows; Also Intakes to Ventilators Near Sill, and Outlet Flues Projecting from Roof.

and (3) through flues which are constructed in various ways. The direct openings are the least satisfactory of all methods because they allow a direct draught on the animals and also allow dirt to blow directly into a stable. The cracks in a poorly constructed barn would come under this heading, although it is safe to say that in most cases no thought of ventilation was in the minds of the builders of such buildings. The fact that ventilation does take place through these cracks is merely an accident.

The cloth curtain system is an example of ventilation through a porous membrane. The action of this system of ventilation depends on osmosis—the passing of fluids of different density through a porous membrane, with a tendency to establish an equilibrium. The

air on the inside of the building is warmer and therefore less dense than the air on the outside, and there is an exchange through the cloth curtain. This method has the advantages of: (1) preventing draughts on the animals; (2) it is easy to install, and (3) it is inexpensive. Its chief disadvantages are that (1) no definite amount of square feet of cloth required per cow has ever been worked out, (2) the cloth curtain may easily become clogged with dust and dirt and has to be renewed. A cloth curtain should never be installed in place of a window. While some light will filter through a cloth curtain, it can never take the place of glass in lighting a stable. A cloth curtain should always have a tight-fitting, sliding, wooden shutter in front of it in order to control the temperature during cold weather.

The best type of flue system of ventilation is that devised by Prof. F. H. King of Wisconsin, and which bears the name of the King system of ventilation. In this system the flues are usually built between the studding of the building and it is best to insulate them with building paper so that they will be perfectly tight and be affected as little as possible by changes in temperature. In remodeling an old barn it is sometimes impossible to build the flues between the studding, and in such instances they may be built on the inside of the stable. It cannot be denied that flues so located are more or less annoying, as they form a projection into the stable and it is sometimes difficult to avoid hitting these projections when carrying on the necessary work in the stable, or to prevent the animals from running into them.

It is claimed by some, that these ventilating flues should be constructed of wood, as metal flues, on account of being cold, are liable to condense moisture on the inside of the flue. This is said to be especially true of the outlet flues, which carry away the moist air from the stable. The opening of the intake flue is usually near the sill of the stable and the outlet of this flue is just under the ceiling on the inside of the stable. The air is forced into the flue by wind pressure at the opening near the sill of the stable. The flue is usually warmer than the incoming air, being warmed by the heat from the bodies of the animals in the stable. This, together with the wind pressure, causes the air to rise in the flue and enter the stable near the ceiling. Being colder than the air in the stable it is

heavier, and therefore settles over the animals, thus tending to keep up a diffusion of air in the stable.

The flue for carrying off foul air has its opening near the floor, on the theory that CO_2 is heavier than air. Some recent experiments have shown that despite its density more CO_2 is found near the ceiling than was formerly supposed. An opening should therefore be provided in the ceiling to carry off foul air and also to regulate the temperature, which is certain to become higher than is desirable during certain seasons of the year. All outlet flues should extend above the peak of the barn in order to get the full sweep of the wind, as it is this force which causes the outlet flues to work. If outlet flues are led out of the side of a roof and do not extend above the peak of the barn, wind pressure against that side will force air down the flues. Outlet flues should be provided with a cap or cowl to prevent rain and snow entering them. Oftentimes the flues have their outlet in the cupola of the barn and this cupola is sometimes so constructed that the flue is protected from the wind and sufficient force is not provided to draw air out of the stable. The cowls manufactured by firms making a specialty of ventilating systems are designed with the idea of overcoming this difficulty.

All flues should be provided with dampers so that the amount of both ingoing and outgoing air can be regulated. If this is not done there will be certain times of the year when the temperature of the stable will be anything but satisfactory. Dissatisfaction is often expressed with flue systems of ventilation because they do not work, and an investigation shows that the trouble is due to the effect of counter currents of air. Most systems of ventilation are installed on the principle that there are no other openings for admitting or removing air other than those provided by the flues themselves. If hay chutes or a door are left open, it is quite likely to prevent the proper working of a ventilating system.

The exact number of square inches of ventilating surface which should be allowed per cow is a matter of considerable difference of opinion, and when one stops to consider the factors which influence ventilation, it is not to be wondered at that this is the case. Velocity of wind would alone give opportunity for a great difference of opinion in regard to the proper size of ventilating flues. All authorities agree,

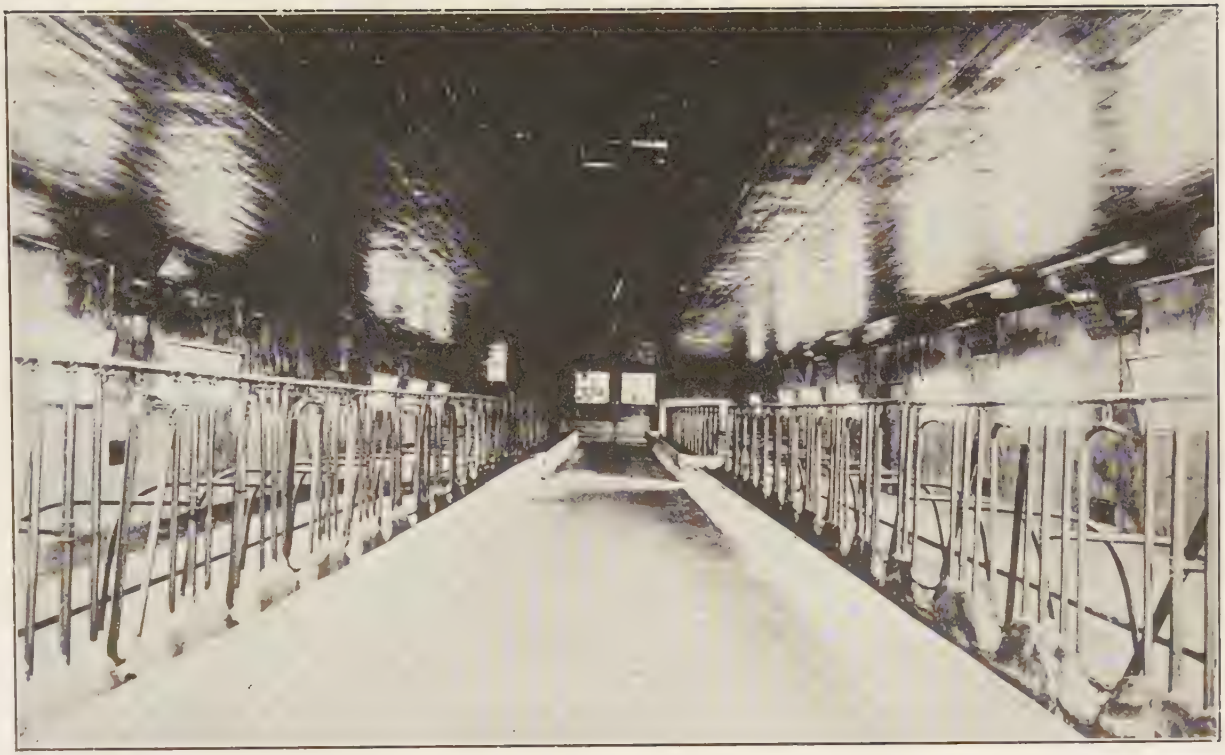


FIG. 32. Interior View of Barn for Certified Milk Production. (Courtesy S. L. Stewart, Newburgh, N. Y.)

however, that inlet flues should be comparatively small and outlet flues comparatively large. One [102] rule which has given good results is to provide 40 square inches of inlet and 40 square inches of outlet flue space per cow, and to make each inlet flue as small as is practicable, and each outlet flue as large as practicable. This number of square inches inlet per cow is larger than is usually advised, but it has the distinct advantage of making possible the circulation of a large volume of air during warm weather. If the inlets are provided with shutters as they should be, this circulation may be checked if desired in cold weather. One outlet flue should be provided for about 20 cows and six or seven inlets should be provided for each outlet.

Professor King [103] has shown that the height of the outlet flue is important and that a flue 40 feet high is nearly twice as efficient as one 30 feet high.

One of the most important features of a flue system of ventilation is to provide each inlet and outlet flue with dampers so that the amount of ingoing and outgoing air may be regulated. If this is not done, no control over the temperature of the stable can be maintained. A temperature of 50° F. is desirable for a cow stable although a few degrees' variation either way may be allowed without serious results.

It may seem from the facts given above that ventilation is such a complicated subject that the dairyman would be unable properly to manage a system after it was once installed. The only way to judge of the efficiency of such a system is to note conditions in the stable, especially on first entering it in the morning. If the air does not have a bad odor, or is not stifling, and if there is not undue moisture as would be shown by precipitation on the walls and windows, the indications are that the system is working properly. The temperature has to be controlled by the dampers in the flues and, as has already been mentioned, by lowering windows and opening special warm air outlets in the ceiling.

[102] This data in regard to the size and number of ventilating flues was kindly furnished by S. L. Stewart Brookside Farm, Newburgh, N. Y. Mr. Stewart has erected many dairy barns, in which the ventilating system has been highly successful.

[103] King, F. H., Ventilation for Dwellings, Rural Schools and Stables, Madison, Wisconsin. (Used by permission.)

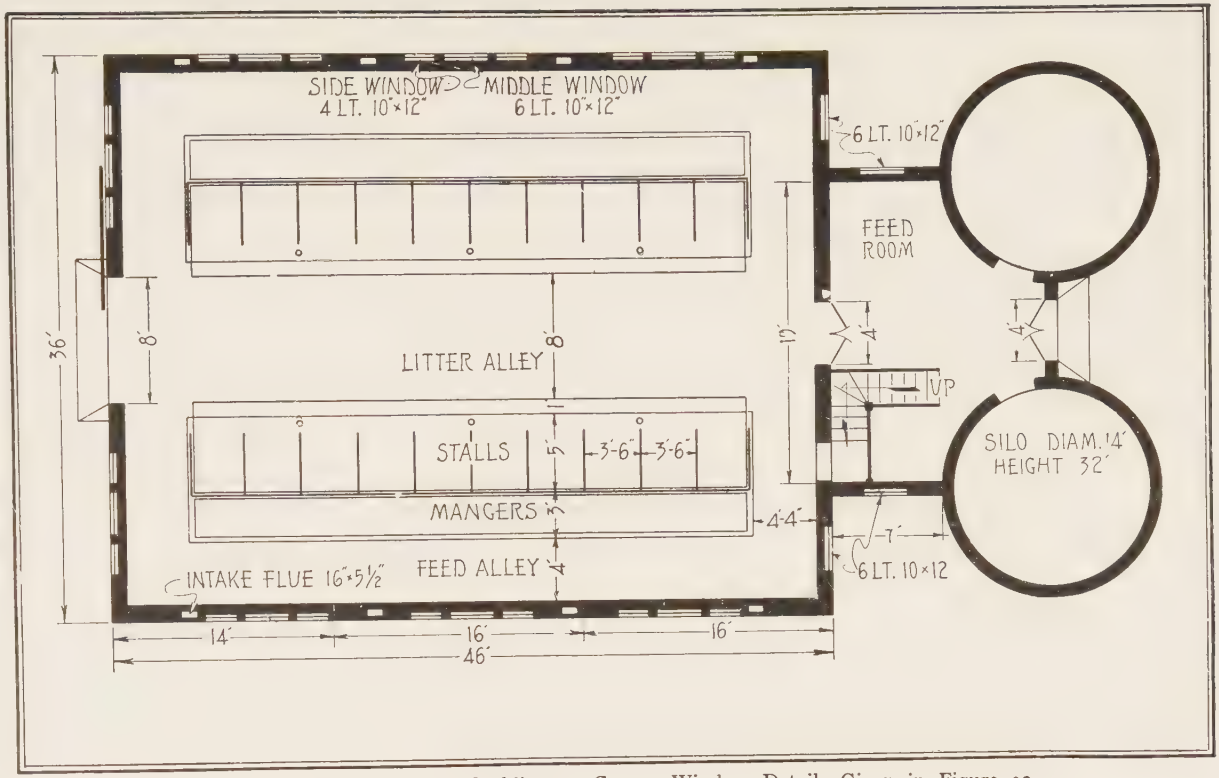


FIG. 33. Floor Plan of Dairy Barn for Stabling 20 Cows. Window Details Given in Figure 30.

THE MILK HOUSE

The type of milk house will depend entirely on the kind and amount of dairy business which will be conducted in it. The term "milk house" has been used to designate a building ranging all the way from a small room, of the simplest construction, to a fair-sized milk plant. This rather loose application of the term milk house has been brought about by the fact that many farmers operate a milk route and oftentimes purchase considerable quantities of milk. It is sometimes necessary to pasteurize this milk and even make up the surplus into dairy products, and in this case the building is really a milk plant rather than a milk house, as the meaning of that term originally implied.

The reasons why a farm milk house is desirable as as follows:

1. To have a special clean place to strain and cool milk.

2. To have a special clean place to store milk, in a room free from dirt, flies and undesirable odors.

3. The proper use of a milk house has a good psychological effect in regard to all points connected with the production and handling of clean milk.

Like the dairy barn, the milk house should be located in a place free from contaminating surroundings. The contaminating surroundings would include the same list mentioned under the contaminations of a dairy barn. Especial care should be taken to protect the milk house from contamination from the manure pit, and if possible it should be located in a sheltered place, as dust and dirt blowing into it may cause a great deal of bacterial contamination. Most milk companies require that it be separate from the stable, although in some cases it may be connected with the stable by means of a short passageway. This method of connecting the two is an excellent one as it almost entirely eliminates the danger of having dust and dirt blow into the milk when it is removed from the stable for straining. If the stable is kept in the proper condition, there is very small chance of the milk taking up undesirable odors from the barn. The milk house should be located near the driveway, so that the milk may be loaded directly into the wagon or truck in which it is delivered, but at the same time it should not be located on a dusty road, as road dust is loaded with bacteria.

It is also desirable to have the ice house as convenient as possible, but it is not a good plan to build the milk house inside of the ice house. The sawdust or other insulating material used to protect the ice from melting is always working into the milk house and tends to keep the house in an untidy condition. If wild grass or straw is used to cover the ice, these may be a source of spore-bearing bacteria which sometimes causes untold trouble with a milk supply. The idea in the minds of those who build a milk house inside the ice house is to have the ice supply help to cool the milk house. If the ice supply is insulated as it should be to keep it from wasting, the ice will be of almost no value in keeping the milk house cool.

The premises surrounding the milk house should be kept neat and clean, and in no wise should barrels of refuse or garbage be stored near it. It is a good plan to have as much of the space as possible immediately surrounding the milk house seeded to grass, as this tends to prevent dust blowing into the building. It is realized of course that this is not always possible, and it has already been pointed out that for the sake of convenience some of the space should be devoted to a driveway.

The milk house may be constructed of any material desired, with one exception—the floor should be of cement. We do not believe that when durability is considered, the cement floor is any more costly than a wooden floor, and in a place where there is bound to be as much dampness as in a milk house, it is very difficult to keep a wooden floor in a proper sanitary condition. The floor should be provided with a drain, which in turn should be provided with a trap to prevent odors from the cesspool rising into the room. The drain will in the majority of cases be most convenient if it is located in the center of the room and the floor should slope towards it, the slope being at the rate of one-fourth inch to the foot. This will insure water being carried away readily.

In case the entire wall of the milk house is not made of cement, it is an excellent plan to have cement construction extend at least 18 inches above the floor. More or less water is bound to get on the walls near the floor and if they are constructed of wood, they will in time decay, and must be replaced. Keeping wooden walls well painted will be of great aid in protecting them against decay, and as a matter of fact the entire inner wall surface of the milk

house should be painted with enamel paint, as this makes it much easier to keep the walls clean. In cases where wooden walls extend to the floor of the room, painting them thoroughly and then covering them with galvanized iron for a distance of 18 inches to 24 inches from the floor will greatly aid in preventing decay.

The milk house should be well lighted and the windows should be hinged at the bottom to prevent the direct entrance of dust into the room. Screens should also be provided for the doors and windows during the fly season. Some provision should be made for ventilating the building and in a small room this can usually be accomplished by means of the windows and a flue placed in the ceiling of the room. This ventilating flue should be provided with a hood or cap to prevent rain and snow coming down it, and it should also be equipped with a damper to regulate the escape of air during cold weather.

The size of the milk house will depend entirely upon the amount and kind of business to be carried on in it. On the ordinary dairy farm the only object of the milk house is to provide a suitable place for straining, cooling and storing milk for a short time. With this idea in view it is poor policy to construct a building any larger than is necessary for the purpose intended, as there is always the temptation to use the extra space for purposes other than the care and handling of milk.

THE MILK TANK

Every milk house should be provided with a milk tank and this should be constructed of cement. Wooden tanks are very short lived and if milk is spilled into the tank and decays, it very easily gets into the fiber of the wood and causes unsanitary conditions. Galvanized iron tanks are sometimes used for small amounts of milk. One of the chief objections to a galvanized iron tank is the fact that it is a good conductor of heat or cold and for that reason it is wasteful of ice.

The size of the milk tank will depend on the number of cans to be placed in it. It should be at least 18 inches wide to provide for a single row of cans. This allows a 2-inch space between the can and the walls of the tank. This 2-inch space allows cracked ice to surround the can and this space should be provided between the cans

themselves as well as between the can and the walls of the tank. Allowing 14 inches for the width of a can and a 2-inch space between each one of them, the necessary length of a tank to contain any desired number of cans may be computed. If desired, more space may be provided for between cans, although it is not good policy to allow too much space as an undue amount requires larger quantities of ice to cool the milk and hold it at the proper temperature.

If the milk tank is constructed of cement the walls should be 6 inches thick, and it is best to insulate them in order to conserve ice. The insulation may be accomplished with 2-inch cork board which has been treated with some preparation to make it waterproof. Preparations are on the market for this purpose and the manufacturers of cork board sell a waterproof paint which is easy to apply and which works well. When cork board is used 2 inches of concrete construction can be built each side of the cork board, thus making a 6-inch wall. Two and one-half inches of concrete can be laid on the upper edge of the cork board to form the top of the walls of the tank. The side of the tank where the cans are lifted in and out should be faced with channel iron. This will prevent the bottoms of the cans from chipping the sides of the tank as they are certain to do unless some protection is afforded. A strap iron is better than nothing but it does not afford the protection that is offered by a channel iron. The bolts for holding this iron should be laid in the concrete when it is soft at the time the walls are being constructed.

The walls of the tank should be 29 inches high from the bottom of the tank to the under side of the cover. This will allow storage of the cans with the covers tipped, as some regulations require that the milk be stored in this manner. With the walls of the tank 29 inches high, it is quite difficult to lift a can filled with milk in or out of the tank. For this reason the bottom of the tank should be sunk below the level of the floor of the milk house. The exact distance to which the bottom of the tank should be sunk is optional, but the wall need not necessarily extend more than 8 inches above the floor of the milk house. This is high enough to prevent water and dirt getting from the floor into the tank. A drain should be provided in the bottom of the tank as otherwise it is almost impossible to keep the tank in a clean, sanitary condition. Even with

the greatest care some milk will be spilled into the tank and more or less dirt will get into it.

When cans are set into the tank the level of the water is raised and some means should be provided for carrying off this surplus water. It is possible to do this by inserting pipes in the side of the tank and have the excess water flow on to the floor and be drained off through the floor drain. This causes an excess of water on the floor of the milk house which is always more or less objectionable. The best method of taking care of this overflow water is by means of a 3-inch stand pipe which may also be used as a drain for the bottom of the tank.

The easiest and most economical method of installing the stand pipe is to make a hole of ample size in the bottom of the tank when it is being built. Into this opening a hard wooden plug can be driven and the 3-inch stand pipe, properly threaded on the bottom, may then be screwed into a hole drilled into the wooden plug. An ordinary iron nut may be used in place of the wooden plug, but in time the threads will wear out and it is rather difficult to cut the old nut out of the concrete and replace it with a new one; also the stand pipe and nut, in the presence of so much moisture, are very liable to rust together and make it very difficult to remove the stand pipe when it is desirable to clean the tank. The wooden plug will in the course of time wear out but it can be easily replaced.

The stand pipe or other overflow pipe should be of such a height that the water level will be maintained at a depth of 20½ inches from the bottom of the tank, if the ordinary 40 quart (10 gallon) milk can is used. This will insure the surface of the water being on a level or slightly above the level of the milk in the can. The stand pipe will be least in the way of milk cans if placed near the corner of the tank, although it should not be placed so close to the wall of the tank that it is impossible to get the jaws of a pipe wrench around it.

It often happens that the amount of milk to be stored in the tank is variable at different seasons of the year, and that a tank large enough to hold the maximum number of cans would be far too large for holding the cans at a time of minimum production. This trouble can be obviated by building a cement partition in the tank and connecting the two compartments by means of pipes placed in

the dividing partition. The pipes may then be plugged when only one side of the tank is in use. One of these pipes should be quite large, say 2 inches in diameter, and placed nearly on a level with the floor, so that the water in the bottom of one compartment can flow into the other compartment where the drain is located. This will remove the necessity of having a drain for each compartment.

The milk tank should be provided with a tight-fitting wooden cover to prevent radiation and thus conserve the ice in the tank. If the tank is long, it is best to build the cover in sections so that it will not be so heavy to lift. Weights suspended by a rope running through a pulley in the ceiling above the tank may be used as a counter poise to help raise the tank covers.

The milk house will be more convenient if it can be supplied with running water. This is of course not always possible, but provision should at least be made for pumping water to the milk house.

In the illustration (Fig. 34) is given in detail the plan of a simple milk house [104] together with a detailed plan of the milk tank.

In designing this milk house it was intended that it be used only for straining and cooling milk in a tank of ice water and storing the milk for a short time. No space is provided for a surface cooler.

No insulation was provided in designing the tank, which is to be constructed with a partition to provide for can space with a varying milk supply. Running water is provided for each compartment through a single supply pipe equipped with a tee and two faucets. This supply pipe is introduced through a pipe sleeve so that the supply pipe may be renewed when necessary without cutting into the concrete.

Weights are suspended from the ceiling by a rope, running through pulleys, to hold the can upright in a tank of ice water until enough milk has been added to the can to cause it to rest on the bottom of the tank. This device makes it possible to place the can in ice water when empty and so hasten the cooling process. A cover is provided for each compartment of the cooling tank and the fronts of the covers have a drop board, the inner surface of which rests against the outer surface of the front of the tank. The detailed plan of the tank shows space for two rows of cans.

[104] Ross, H. E., and Riley, H. W., A Simple Milk House, New York State College of Agriculture at Cornell University.

It is intended that the milk utensils be washed in some place other than the milk house, but a rack built of angle iron is provided for storing the utensils after they are washed. The bottom of the shelf is placed 12 inches from the floor.

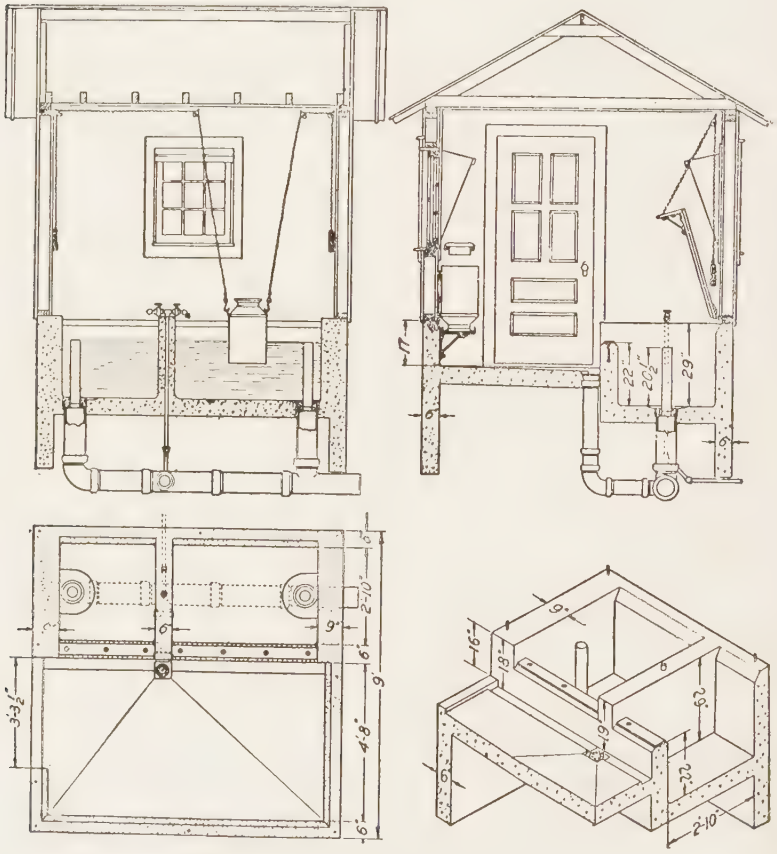


FIG. 34. Plan of Simple Milk House.

Figure 35 shows the ground floor plan of a more elaborate milk house. A milk house of this type might be used by a farmer who sold at retail a large quantity of milk, either produced by his own herd or purchased from neighboring farmers. It might also be used as a

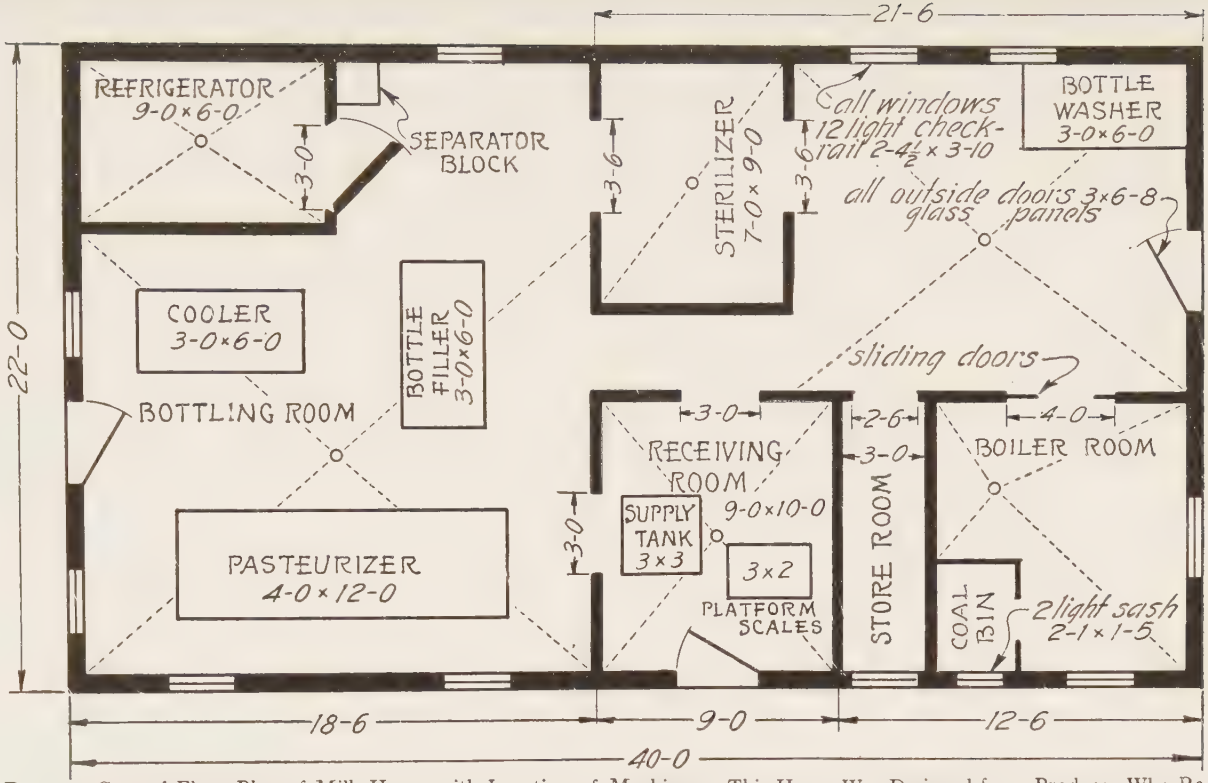


FIG. 35. Ground Floor Plan of Milk House with Location of Machinery. This House Was Designed for a Producer Who Retails His Own Milk and Possibly Buys Some of His Neighbors.

small city milk plant, although as such the receiving room would need to be enlarged and more space provided for bottle storage.

It will be noted that there are two doors to the sterilizer. These are placed directly opposite one another with the idea that all small utensils such as pails, cans, dippers and bottles enter the bottling room through the sterilizer. These utensils are the ones most liable to carry disease-producing bacteria and a good sterilization before they are taken into the room where the milk is actually handled and prepared for market is an added safeguard against spreading disease.

The sterilizer is best made of well-reinforced concrete, with walls 6 inches thick. The bolts to which the door hinges are fastened should be put in place when the concrete is soft. A sufficient number of these should be provided so that the hinges will be held securely in place and not allow the door to sag. If it is intended to place a rack in the sterilizer for holding small utensils, the bolts supporting this rack should also be set before the concrete hardens. Such a rack should preferably be made of angle iron or galvanized iron pipe.

The door of the sterilizer is important as it must fit snugly and prevent as much steam as possible from escaping. This is best done by building on the inner surface of the sterilizer door a projection 2½ inches thick, which extends into the sterilizer and fits against the sides of the opening in the sterilizer. The door proper, to which this projection is attached, should be 3 inches larger than the opening. The entire door should be covered with tinned copper, and the different sheets of the metal well soldered. The 3-inch surface of the door which extends beyond the opening should then be covered with felt, and when the door is closed this felt-lined flange fits snugly against the concrete wall of the sterilizer and helps very materially to prevent the escape of steam. Some type of door fastener should be used which will draw the door tightly shut.

The pipe which supplies steam for the sterilizer should run the entire length of the room, near the floor. The end of this pipe should be capped, and the steam allowed to escape through holes of about one-fourth inch in diameter, which are bored at intervals of about 4 inches.

While it is not absolutely necessary, a 6-inch galvanized iron ventilating flue, leading out of the top of the sterilizer, is of great advantage.

This flue should be provided with a sliding damper and opened just before the utensils are to be removed from the sterilizer. This will allow the steam to escape suddenly and prevent its condensing on the utensils, which will then dry from the heat in the sterilizer. This tends to prevent their rusting.

The floors of the milk house should be of concrete. They should

FIG. 36. A Serviceable, Simple Milk House.

slope towards the drain in each room, and the slope should be at the rate of one-fourth inch to the foot.

The refrigerator is designed to hold a small amount of surplus milk, and milk which is bottled for delivery. It is cooled by ice placed in an overhead bunker or it can of course be cooled by brine coils if the business is of sufficient size to warrant the installation of a compressor. If the ceiling is too low to admit of an overhead ice bunker, cakes of ice may be piled in the room, but this ice takes up valuable space and keeps the room in a more or less damp condition. It will be found advantageous to line the refrigerator with some insulating material such as cork board which has been previ-

ously waterproofed. The cork board should then be covered with a coating of cement.

If the topography of the ground will allow of the type of construction, it will be found advantageous to raise the level of the receiving room 4½ feet above the level of the other rooms in the building. This will allow the milk to flow by gravity to any one of the different pieces of apparatus, such as the pasteurizer, cooler or bottle filler.

All construction should be as smooth as possible, and all corners of the floors and walls should be filled with cement and well rounded so that dust and dirt will not accumulate in them.

Chapter XVII

DAIRY BUILDINGS (*Continued*)—THE COUNTRY MILK STATION

The country milk station plays a very important part in the system of milk distribution. Many of these stations are located in small villages and in many cases they are the chief meeting place of the farming community from which the supply of milk is drawn. They are usually looked upon with a great deal of favor by local merchants, as the milk producers naturally do much of their trading when they deliver their milk and the activity occasioned by the delivery of milk is always a source of interest to the village inhabitants. Frequently the convenience of train service is increased in a village because of the location of a milk station, as oftentimes the train which carries milk will also carry passengers. In short, the country milk station ceases to be a mere place where milk is received and shipped, but rises to the dignity of an institution.

The manager of a country milk station has the opportunity to do a great amount of good in encouraging the production of clean milk. While there are rules and regulations which are enforced on the milk producer, yet it is much more effective if he can be made to feel that it is to his interest to produce clean milk, and that the interests of the producer and milk buyer are one. If the station manager possesses the necessary skill and tact, he can do much to bring about this feeling of coöperation.

The plan of the country milk station will depend entirely on the purpose for which it is intended. If milk is simply received, cooled and shipped in cans, the plan will be simple, but if dairy manufacturing is also to be carried on, or milk is to be bottled, the plan will be more elaborate.

No matter what the purpose of the country milk station, it and its surroundings should be attractive. It is of very little use to talk sanitation to the milk producer if the building where he delivers his

milk is unpainted and in disrepair and the surroundings littered with broken glass, sawdust, discarded machinery or other refuse. It should be stated that most milk buyers recognize the importance of a neat and attractive milk station.

The milk station should be located where it is as accessible as possible. However, the location in a certain place is often a matter of necessity on account of the location of the railroad on which the milk is shipped. If the station is an inland one and the railroad, therefore, not a controlling factor, it is poor policy to locate the building on a side road which is well-nigh impassable during the spring and fall seasons. The roads leading to a milk station are an important factor in its receipts of milk.

One of the first prerequisites of a milk plant is a pure and abundant water supply. In some locations the milk station has the advantage of being able to connect with a municipal water supply. However, in small country places the plant must furnish its own water supply and this may be done by building a reservoir which is supplied by springs, or by drilling one or more wells. A drilled well usually has the advantage over other supplies in furnishing water of low temperature, which is of great aid in cooling milk and cream. Raw water from streams should not be used, for while they may furnish an abundance of water, such a supply offers a possible chance of dangerous contaminations.

In small country places one of the greatest difficulties often encountered is that of sewage disposal. Sometimes the sewage is deposited in streams, but unless there is a large volume of water, the bed of the stream may soon become clogged with a very offensive deposit. There are also in some states stringent laws against this practise, particularly if the stream is stocked with game fish. Some [105] recent work along this line tends to show that creamery wastes are not as harmful to fish as was once supposed and, in fact, that fish may use some of this waste as food. If the soil surrounding the plant is sand or gravel, a series of cesspools will sometimes be adequate to handle the sewage, especially if the sewage consists of floor washings and wash water from dairy apparatus. In no case, however, will such a system take care of sewage in which there is a considerable amount of casein and albumin.

[105] Walker, C. L., and others, Cornell University Bull. No. 425.

Under proper conditions a septic tank will give satisfactory results. While a septic tank will better take care of casein and albumin than will a cesspool, it cannot handle large quantities of these products. In fact, no system of sewage disposal has been found, except a regular city disposal system, which can handle excessive amounts of casein and albumin. Septic tanks will give best satisfaction if the amount of sewage supplied is regular in amount. As would naturally be supposed, the size of the tank is regulated according to the amount of sewage it is intended to handle. If too much or too little sewage is supplied to the tank, it will not work properly and may become offensive.

The receiving platform should be ample in size and should be easily accessible. It should not terminate in a blank wall or other obstruction so that teams or trucks have to back up in order to get away from the platform. If the station is to receive a large quantity of milk, it is well to have the plans so arranged that the patron, after unloading his milk, can drive ahead and receive the washed and sterilized cans at another place. This makes it possible to receive milk much more rapidly than if the cans are returned at the same point where they are received.

Steam pipes should not be allowed to exhaust on the side of the building on which the receiving platform is located. This causes great annoyance by frightening horses and may be responsible for serious accidents.

While not an absolute necessity, a cement driveway in front of the receiving platform is desirable. This should have a slight slope toward a drain, as this arrangement makes it possible to keep the premises in the immediate vicinity of the platform neat and clean. It is well to have a roof over the driveway as this will protect patrons from the rain and snow when unloading milk in inclement weather. If the milk plant is a large one, a railroad siding will be necessary, both for loading milk and receiving supplies such as coal, bottles, cans, etc. In some instances milk is received from outlying points by train or by trolley and in such a case a railroad siding is imperative.

The boiler room and coal bins should be so located that they will not be a constant source of contamination to that part of the plant where milk is handled. If large quantities of coal are used, the rail-

road siding already mentioned will be useful and economical in unloading coal, and such a siding will be most useful for this purpose if it is provided with a trestle. Every milk plant should have a storeroom for holding supplies, and if the plant is a small one, this may often be located in the attic. If the plant is large, a well-organized stockroom is a necessity. Like the boiler room, the storeroom should be in some place away from the milk rooms, so it will not be a possible source of contamination.

In a small milk plant necessary repairs to machinery may be done in the boiler room and in planning a milk station the boiler room should be built large enough to contain a work bench. Nearly all large milk plants find it necessary to maintain a regular repair room. The importance of being equipped to make the ordinary repairs to machinery cannot be overestimated. The actual cost of making any necessary repairs is not the question of greatest importance, but inability to repair a machine as soon as it is broken may mean the spoilage of dairy products, the value of which would pay for the repairs many times over.

Some large country milk stations are equipped with ice-making machinery, but nearly all country plants must depend for refrigeration on natural ice. It is important that ample provision be made for storing enough ice for all possible needs. The ice house should be conveniently located, but it should be so placed that sawdust or other insulating material will not be constantly brought into the milk-handling rooms and so be a constant source of contamination. A room or platform should be provided for washing ice before it is brought into the plant for use. Insulating materials, and especially sawdust and shavings, not only are a possible source of contamination, but they will clog machinery and drains, and this causes untold annoyance.

In planning a milk station, the possible future needs of the building should be carefully studied. Possible increase of the milk supply is a question which should receive careful consideration, as should also the question as to the future necessity of manufacturing certain dairy products. It is much easier and more economical to provide for possible contingencies at the time the building is constructed than it is to make additions and changes after the building is erected.

Figure 37 is a floor plan of a milk station designed to receive

15,000 pounds of milk daily. Following the plan is a list of equipment which should be used in a milk station of this type.

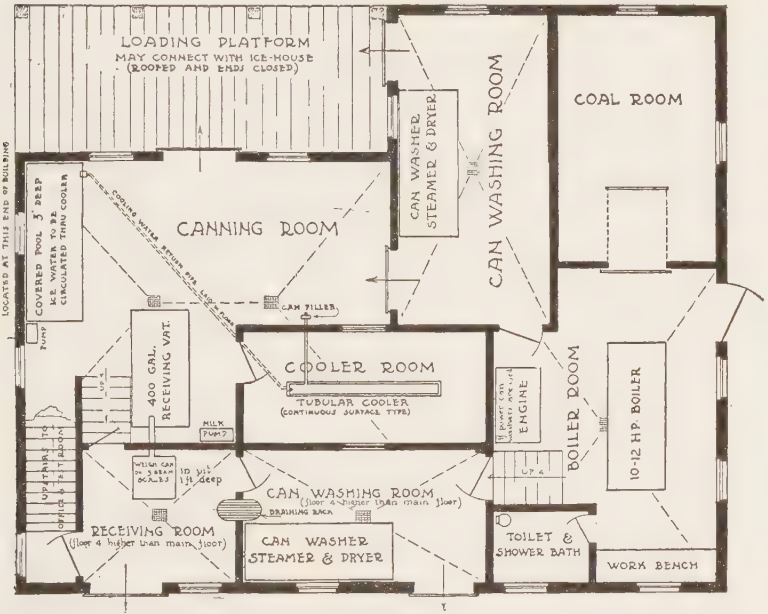


FIG. 37. Floor Plan of Cooling and Canning Station, 15,000 Pounds Capacity.

EQUIPMENT FOR COOLING AND CANNING STATION, CAPACITY 15,000 POUNDS MILK

The floor plan for this station is given in figure 37.
One 10 to 12 horse power boiler with safety valve, steam gauge, water column, injector, and so on
One 10 to 15 barrel steel tank for boiler water supply
One 4 horse power engine, if power can washers are used
One water pump, if plant is not supplied with running water
Two double-compartment sinks for washing cans, or two power-driven washers
One 5-beam scale, capacity 600 pounds
One weigh can, capacity 600 pounds
One milk can drainer
One conductor head and pipe to reach vat
One milk vat, capacity 400 gallons
One milk pump, capacity 6000 pounds per hour
One water pump for circulating ice water through cooler
One tubular milk cooler, surface type, capacity 6000 pounds per hour
One 24-bottle Babcock tester with apparatus
One table

Necessary steam and water pipe and fittings
Necessary shafting, pulleys, and belting
Necessary sanitary pipe and fittings
Toilet room fittings
Office furniture

UTENSILS AND SUPPLIES

One 14-inch adjustable pipe wrench
One 10-inch adjustable pipe wrench
One 10-inch monkey wrench
Boiler firing equipment
Set of tools, Soldering outfit } not necessary but desirable
One-half pint milk sample bottles with ground glass stoppers
One sampling tube or dipper
One dozen milk sheets
Office supplies, stationery, and so on
One-half dozen pails
One barrel washing powder
Brushes for washing cans, vats, piping, floors, and the like
One barrel each steam cylinder and machine oil
One dozen dairy thermometers
Four hundred 10-gallon milk shipping cans (patrons' cans not included)

Figure 38 is the floor plan of a milk station in which, in addition to the handling of milk, it is designed to manufacture cottage cheese. Following this plan is a list of the equipment which would be used in this building.

EQUIPMENT FOR CREAM-SHIPPING STATION IN WHICH COTTAGE CHEESE IS MADE, CAPACITY 10,000 POUNDS MILK

The floor plan for this station is given in figure 38.
One 12 to 18 horse power boiler, with fittings
One 15 to 20 barrel steel tank for boiler water supply
One water pump, if plant is not supplied with running water
Two double-compartment sinks for washing cans or two power-driven washers
One 5-beam scale, capacity 600 pounds
One weigh can, capacity 600 pounds
One can drainer
One conductor head and pipe to reach vat
One milk vat, capacity 300 gallons
One milk pump, capacity 6000 pounds per hour
One pump for circulating cooling water through pasteurizer
One separator, capacity 3000 to 4000 pounds per hour
One milk heater, capacity 6000 pounds per hour
One cream pasteurizer, capacity 250 to 300 gallons
One Babcock tester and apparatus
Two wash sinks

One table
Two jacketed cheese vats, capacity 500 gallons each
Necessary shafting, pulleys, belts, and the like
Necessary steam and water pipe and fittings
Necessary sanitary pipe and fittings
Office furniture
Toilet room fixtures

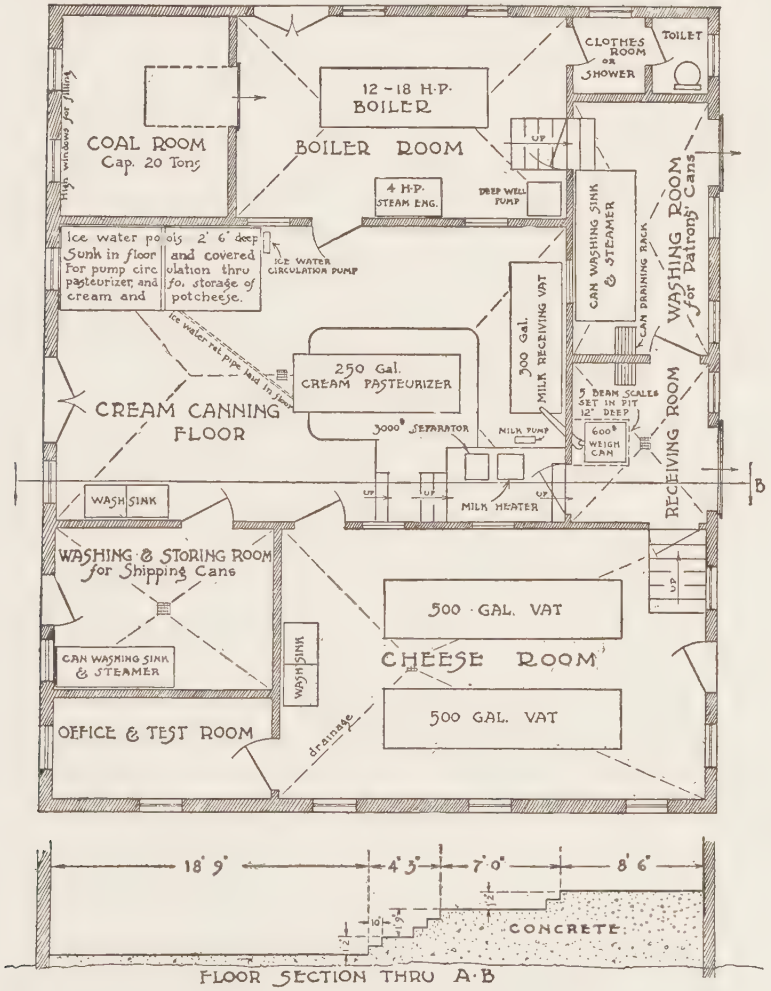


FIG. 38. Cream-shipping Station with Equipment for Making Cottage Cheese, Capacity 10,000 Pounds Milk.

UTENSILS AND SUPPLIES

Boiler firing equipment
One 14-inch adjustable pipe wrench
One 10-inch adjustable pipe wrench
One 10-inch monkey wrench
Set of pipe tools } not necessary but desirable
Soldering outfit }
One barrel each steam cylinder and machine oil
One barrel washing powder
One-half dozen pails
One dozen dairy thermometers
Brushes for washing cans, vats, sanitary pipe, sample bottles, and the like
Milk sample bottles with ground-glass stoppers
One sampling tube or dipper
One dozen milk sheets
One hundred 10-gallon cans for handling and shipping cream and pot cheese (patrons' cans not included)

It has already been pointed out that the future use of a milk plant must be taken into account when plans are being prepared for its erection. The necessity for doing this will be apparent to any one studying these plans. The difficulty of remodeling the building shown in figure 37 to suit the requirements of the building in figure 38 is also apparent. These plans and lists of equipment were taken from Cornell Extension Bulletin No. 30.[106]

In studying these plans, it must be borne in mind that they will not apply to all conditions. They will, however, be suggestive and by making necessary alterations, they may possibly be made to apply to different conditions.

The lists of equipment are also not necessarily complete. However, the main pieces of equipment needed are given under each set of plans.

[106] Stocking, W. A., Ayres, W. E., Potts, Roy C., and Meyer, H. F., Country Milk Stations—Function, Organization, Operation, Construction and Equipment, Cornell Univ. Ext. Bull. No. 30.

Chapter XVIII

DAIRY BUILDINGS (*Continued*)—THE CITY MILK PLANT

The location of the city milk plant is oftentimes a matter of necessity rather than a matter of choice. This will, to a certain extent, influence the general arrangement of the building. In country

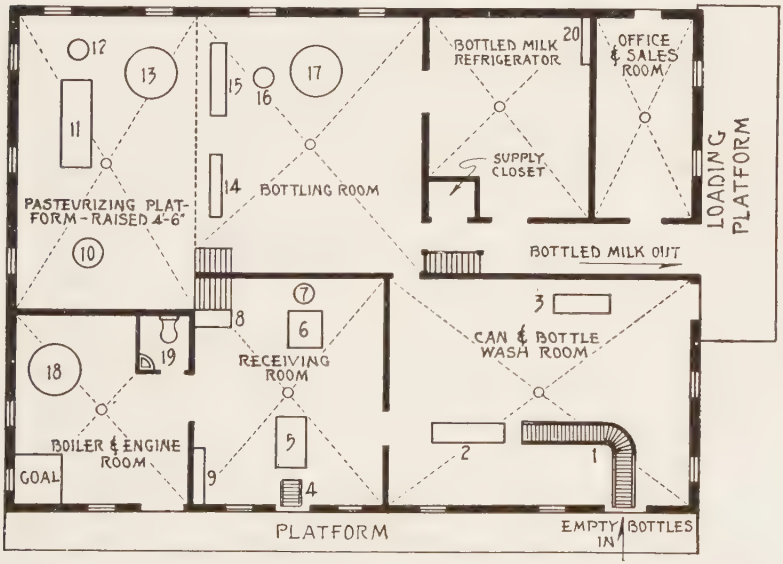


Fig. 39. Floor Plan of a One Story City Milk Plant. Toilets, Cloak Room and General Storage in Basement. (1) Can Conveyor, (2) Can Washer, (3) Bottle Washer, (4) Can Conveyor, 18" Up, (5) Weigh Tank, (6) Receiving Tank, (7) Milk Pump to Pasteurizer, (8) Wash Sink, (9) Sample Bottle Rack, (10) Clarifier or Filter, (11) Pasteurizer, (12) Milk Pump, (13) Milk Storage Tank, (14) Sanitary Pipe Sink, (15) Milk Cooler, (16) Milk Pump, (17) Bottle Filler, (18) Boiler, (19) Toilet, (20) Service Refrigerator.

districts where land is cheap, the milk plant may be spread out over as much ground as is desirable, but in the city where land costs are high and conditions are congested, it is often necessary to build

the milk plant several stories high in order to get enough floor space to carry on the work. In the erection of any dairy plant close attention should be given to convenience and to the utilization of space, but particular attention should be given to these two points in erecting a city milk plant.

Other things being equal, the one-story plant gives the best satisfaction. Some of the main objections to a milk plant more than one story high may be summed up as follows: (1) supervision of operation is much more difficult; (2) it is difficult to move heavy machinery; (3) trouble is often experienced in making floors waterproof; (4) difficulty in putting up and taking down sanitary pipe; (5) necessity of boring through concrete floors when new pipe lines are installed; (6) more difficult to provide proper ventilation and also to dispose of exhaust steam from steam-driven machinery, such as pumps, turbine separators and testers; (7) more difficult to arrange and maintain a drainage system; and (8) more difficult to secure good light.

In an investigation carried on by the Bureau of Dairying, United States Department of Agriculture, 140 out of 181 dealers favored the one- or two-story milk plant in preference to higher ones. The following table taken from milk plant letter No. 114, Bureau of Dairying, United States Department of Agriculture, gives a good idea of the opinions of 61 practical milk dealers in regard to the height to which a milk plant should be built:

Table 69.—Type of Plant Preferred by Various Dealers.

No. of Gallons Handled Daily	Number of Dealers Favoring				
	One Story	Two Stories	Three Stories	Four Stories	Total Reporting
Less than 100	3	..	..	..	4
100– 250	5	1	..	..	6
250– 500	9	10	..	..	19
500– 1,000	8	14	2	..	24
1,000– 1,500	7	13	4	..	24
1,500– 2,000	6	7	3	..	16
2,000– 3,000	3	7	1	..	11
3,000– 5,000	8	10	8	..	26
5,000– 8,000	5	8	11	..	24
8,000–10,000	1	2	3	..	6
10,000–15,000	4	1	3	..	8
15,000 or over	2	5	4	2	13
Totals	61	79	39	2	181

Some city milk dealers have in mind supplying a certain trade and accordingly they build the plant in the neighborhood where that trade exists. This sometimes very materially lessens the distance it is necessary to travel in distributing the milk. Others locate the plant with reference to railroad facilities, and this is in some cases very desirable where the bulk of the milk supply is received by railroad or trolley. In our largest cities it is impossible to give much consideration to either of the above-mentioned points. Building space is so expensive that the dealer must locate where he can afford to build.

There has of late years been a tendency on the part of some city milk distributors to compete with one another in erecting milk plants, and the result has been, in some cases, rather ornate establishments. This condition is rather deplorable, as it adds useless expense to the process of handling milk without any material benefit to the consumer and, in the end, the consumer must pay for it. Convenience, serviceability, durability and sanitation are the four main features which should receive attention in constructing a city milk plant.

In planning a city milk plant it should be the aim to have the milk received at a certain point and go directly through the plant by as direct a route as possible. Particular attention should be paid to the prevention of the interference of milk coming from different machines, as, for example, cans of milk coming from the pasteurizer should not cross the path of crates of milk coming from the bottle filler.

It has already been mentioned that because of the high price of land, city milk plants are frequently built several stories high. In such a plant the milk is received on the ground level and is immediately delivered to the top floor, either in cans, by means of special conveyors, or the milk is dumped and pumped to the top floor. The latter method is the most common, but some authorities claim that the force exerted on the milk by the pumps splits up the fat to such an extent that the cream line will not show as well as on milk which has not passed through the pumps. After reaching the highest level the milk is allowed to flow by gravity back to the ground floor, and on its journey back, it is subjected to the various processes necessary in preparing it for market, such as filtering, pasteurizing, cooling and

bottling. This method does away with the necessity of using as many pumps as would otherwise be necessary.

In some plants the building is built as high as may be necessary and a part of the building is left open from the main floor to the roof. In the place of constructing complete stories, levels or decks as large as may be advisable to hold the different machines are erected. This type of construction is more elastic than one with successive floors or stories and admits of better light and ventilation. With such a type of construction it is also easier for a foreman or manager to supervise the entire plant.

As has already been pointed out in case of the country milk station, the city milk plant should have its machinery rooms, locker rooms and storerooms so located that they will offer the least possible opportunity of contaminating the milk supply. In many city plants a salesroom is maintained and if possible this salesroom should have the following features: (1) It should be attractive; many city dealers make the mistake of placing the salesroom in any left-over space so that goods are not properly shown. (2) It should be of neat sanitary construction and should be well refrigerated. (3) It should be so located that it can be easily stocked from the operating part of the plant. (4) If possible, it should contain an observation window from which may be seen some room in the plant where one or more of the main dairy operations are being carried on, e.g., the bottling room. This is a good advertising feature.

If milk is received in cans, dumped and weighed, and there is any considerable amount of it, a can conveyor is almost a necessity. This conveyor should not run clear to the weigh can, but there should be space enough between the end of the conveyor and the weigh can to allow a person to stand and dump milk. An iron rail should be located in front of the weigh can so that the cans may be leaned against it when the milk is poured into the weigh can. The rail should be from 15 inches to 18 inches high, depending on the preference of the person who dumps the milk. The weigh can should have a large outlet so that as little time as possible will be consumed in emptying it. It is sometimes necessary to elevate the conveyor and the weighing platform so that the milk will flow by gravity into a receiving tank from which it may be pumped to any desired place in the building. Another arrangement is to have the receiving tank

and milk pump in a special pit, but this arrangement is usually not satisfactory as the pit is, as a rule, hard to enter and difficult to keep clean. If there is a floor below the receiving room, a receiving tank and milk pump is frequently located on this floor.

Ample provision should be made for washing and storing both cans and bottles and also for storing bottled and canned milk at low temperatures.

A large and easily accessible loading platform is necessary. In loading wagons for the retail delivery, it is desirable to start them on their routes as soon as possible and when the drivers return with empty bottles and unsold products, they are always anxious to check in and straighten up accounts for the day. A small loading platform makes rapid work of this kind impossible and under cramped conditions the work of the person who checks products in and out is made more difficult. If possible, that part of the platform devoted to loading milk should connect with the refrigerating rooms and, where empty bottles are unloaded, should connect with the wash room. This arrangement is not always possible and power-driven conveyors for carrying milk crates have been utilized effectively, both in transporting crates of bottles filled with milk from the refrigerator to the loading platform, and in carrying empty bottles to the wash room.

Plenty of light should be provided in order that employees may be able to carry on the work. In our larger cities it is frequently necessary to depend on artificial light but in the smaller cities natural light can be secured in most cases by careful attention in placing windows. Steel window frames usually give better satisfaction than wooden ones, as on account of the constant moisture and dampness the latter tend to rot. The panes of glass should not be too large as they are bound to be broken occasionally and large panes are expensive to replace. The main exception to this rule would be in the offices and in an observation window where customers and the general public may watch dairy operations. For the manufacturing rooms a pane of glass 15 inches by 20 inches will be found satisfactory.

All construction should be as smooth as possible with a minimum of ledges for collecting dust and dirt. Frequently necessary ledges and projections can be finished with a rounded surface and this makes it easier to keep such surfaces clean.

Walls and floors should be constructed of some hard smooth material and cement construction has usually given the best satisfaction where durability and economy of construction are considered.

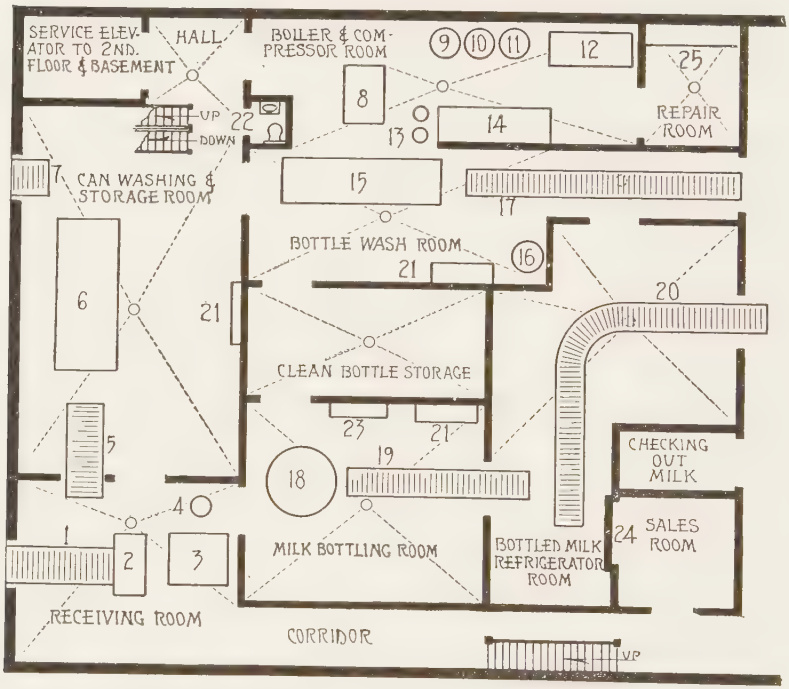


FIG. 40. First Floor Plan of a City Milk Plant, Showing Location of Machinery. (1) Conveyor, (2) Weigh Tank, (3) Receiving Tank, (4) Milk Pump to Pasteurizer Above, (5) Can Conveyor to Washer, (6) Can Washer, (7) Can Conveyor, (8) Boiler, (9), (10) and (11), Compressors, (12) Condensing Coils, (13) Brine Pumps, (14) Brine Storage Tank, (15) Power Bottle Washer and Sterilizer, (16) Brush Bottle Washer, (17) Empty Bottle Conveyor, (18) Bottle Filler, (19) Bottle Conveyor, (20) Bottled Milk Conveyor, (21) Wash Sinks, (22) Toilet, (23) Rack for Small Utensils, (24) Service Refrigerator for Sales Room, (25) Work Bench.

The floor should be waterproofed and this is an absolute necessity if the plant is more than one story high with milk handled in rooms above the first story. The floors should be provided with drains and should slope toward these drains at the rate of one-fourth inch to the foot. If the room is unusually large, it is best to have more

than one drain in it, each drain receiving the water from a certain area of the floor space sloping toward it.

The size of a city milk plant will depend entirely on the amount of milk handled and the disposition made of it. In principle, a city milk plant is not supposed to do manufacturing but it usually is forced to do more or less of this work in order to care for the surplus which every city milk plant must carry. Some milk dealers sell the surplus to dairy manufacturing concerns rather than entail the expense of extra room and dairy manufacturing machinery. The figures in the following table compiled by the Bureau of Dairying,[107] United States Department of Agriculture, gives some idea of the size of different rooms in five modern and well-arranged plants which were under actual operation.

Table 70.—Number of Square Feet in Various Work Rooms of Five Well-Arranged Milk Plants.

Quantity of Bottled Milk Handled Daily Gallons	Receiving Room Sq. Ft.	Bottle Washing Room Sq. Ft.	Pasteurizing Room Sq. Ft.	Bottling Room Sq. Ft.	Total Area for Receiving, Washing, Pasteurizing and Bottling Room Sq. Ft.	Milk Storage Room Sq. Ft.	Clean Bottle Storage Room Sq. Ft.
1000.....	400	600	500	300	1800	450	400
1500.....	....	700	500	375	1625	550	...
3000.....	900	1050	1300	1200	4450	1200	750
4000.....	460	1886	540	700	3586	1426	540
6000.....	1200	1908	720	720	4548	1110	720

If the room is wide enough to admit of the installation of two rows of machinery, and there is a probability of the floor being constantly wet, a gutter in the center of the room 4 or 5 inches deep and 6 to 8 inches wide will be found useful. This gutter may be covered with a removable iron grating so that trucks and other machinery may be easily moved from one side of the room to the other. Drains for carrying off the water may be placed at necessary intervals in the bottom of the gutter. Hot and cold water hose connections should be installed at frequent intervals along the walls. This makes it more easily possible to keep floors and apparatus clean.

If a building is of more than one story, it should be provided

[107] City Milk Plants—Construction and Arrangement, by Ernest Kelly and Clarence E. Clement, Dairy Division, Bull. No. 849, U. S. Dept. of Agriculture.

with a freight elevator. The installation of such an elevator adds considerable to the cost of a building but in a series of years it will pay for itself. Dairy machinery is heavy and awkward to handle, and to move it up and down a stairway is very laborious,

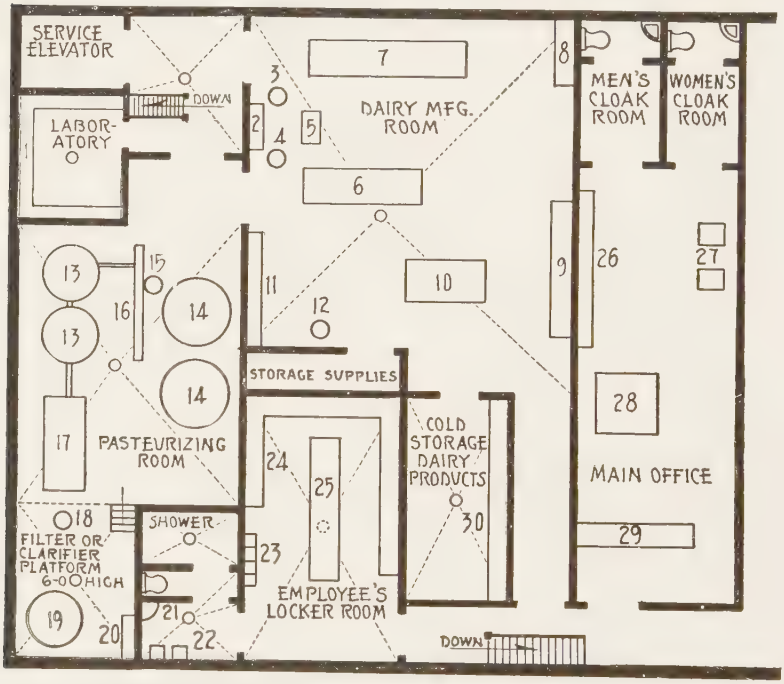


Fig. 41. Second Floor of City Milk Plant. (1) Lead Top Laboratory Table, (2) Separator Supply Tank, (3) Milk Heater, (4) Milk Pump, (5) Separator Raised 30", (6) Cream Ripening Vat, (7) Cheese Vat, (8) Wash Sink, (9) Shelf for Holding Utensils, (10) Churn, (11) Wash Sink for Sanitary Pipe, (12) Starter Can, (13-13) Pasteurizer Holding Tanks, (14-(14) Glass Lined Holding Tanks, (15) Milk Pump, (16) Cooler, (17) Preheater, (18) Milk Pump, (19) Filter or Clarifier, (20) Wash Sink, (21) Urinal, (22) Wash Bowl, (23) Wash Bowls, (24) Employees, (25) Table, (26) Filing Cabinets, (27) Desk, (28) Table, (29) Cashier's Desk.

if not impossible. If the plant is not of sufficient size to warrant installing a power-operated elevator, one operated by hand may be installed. In a plant of any size, the elevator should have a capacity of at least 4000 pounds and it should be long and wide enough to hold the average milk pasteurizer or milk vat.

Chapter XIX

MILK PLANT OPERATION

RECEIVING AND SAMPLING THE MILK

When milk is first received in a market milk plant, samples are nearly always taken for analysis. The number of samples taken and the manner in which they are taken will depend on the kind of analysis to be made of them. If the plant receives milk directly from its patrons and the milk is paid for on a basis of its fat content, it will be necessary to keep a composite sample of the milk, the sample to be tested at the end of 15 days.

If these samples are taken directly from the patrons' can, the milk should be well stirred before the sample is drawn. It takes only a short time for the fat to rise to the surface, and this would make the sample richer in fat than it should be and the plant would pay for more fat than it actually received.

If the patrons' milk is dumped into a weigh can, the milk will in nearly all cases be mixed thoroughly for sampling.

Milk should be received by weight rather than by volume. Since it is cheaper to produce milk which is low in total solids than it is milk high in solid content, the production of the former is encouraged by payment on a volume basis. If milk is bought on a volume basis the producer cannot be wrongfully blamed for making no effort to produce a product which costs him more and for which he receives no additional returns.

Another phase of the question has to do with the increase in the use of fluid milk. A long cream line which in normal milk is quite synonymous with high solid content makes the customer feel that he is getting the worth of his money and that milk is a valuable food. This feeling stimulates consumption of milk.

If milk is bought by volume instead of by weight, the milk is usually measured by means of a stick, graduated to give results

in quarts or gallons when used in a container of uniform size, as for example a milk can. If the can is battered the milk buyer loses, as the can would not hold the volume indicated by the height of the milk on the measuring stick.

FIG. 42. Type of Rotary Can Washer

The following table indicates actual losses [108] which occurred in a city milk plant where the milk was received by measure.

If the milk received is in bulk, as would be the case in a large city milk plant, enough samples should be taken for analysis to keep check on possible adulteration. These analyses are also neces-

[108] Clement, C. C., Milk Plant Operation, U. S. Dept. of Agriculture, Bul. 973.

Table 71.—Showing Difference Between Can Measure and Actual Weight of Receipts of Market Milk in 346 Shipments.

Number of cans received	1,102
Quantity received by can measure	6,185
Quantity received at 8.6 pounds per gallon—pounds	53,191
Quantity received by actual weight, pounds	52,191
Difference—pounds	1,000
Per cent of shortage	1.88

sary in checking up losses within the plant and the percentage of fat in dairy products is usually one of the most dependable bases for computations of this sort.

It may also be desirable to take samples for bacteriological analysis. The results of such analysis show the quality of milk received and make it possible to estimate the value, from a sanitary standpoint, of different dairy practises, such as pasteurization, cooling and holding at different temperatures. These samples should be taken in such a way as to represent the bulk of milk from which they are drawn, and they should be examined at once to prevent increase of bacteria. If samples intended for bacteriological analysis cannot be examined immediately, they should be buried in crushed ice, to prevent increase of bacteria, and such samples should never be held longer than is absolutely necessary.

It should be stated in this connection that one of the greatest values of a laboratory in connection with a milk plant is the detection of sources of contamination. Frequently a piece of dairy apparatus such as a jacketed vat will start leaking and in this way contaminate milk. Improperly washed and sterilized sanitary pipe frequently causes trouble in a milk plant. The quickest and surest method of detecting these troubles is to examine bacteriologically samples taken from various sources.

After sampling the milk, it should be weighed, and to do this each patron's milk is usually dumped into a receiving tank located on a set of scales. If the milk is weighed in a can, either the one in which it is delivered or one belonging to the plant, the actual weight of the can should be known. Cans vary in weight anywhere from one-half to two pounds, and if the weight of the can is assumed to be a certain amount, this variation in weight may make it impossible to keep an accurate check on plant losses. Some companies

check up on the weight of each can and then solder on it a brass tag on which the weight is stamped.

The weight of each patron's milk should be carefully recorded and for this purpose the weigh sheet which has been in use ever since the milk plant system was started, gives excellent satisfaction. Such a weigh sheet has two distinct advantages. It keeps before the eye of the milk weigher the record of the weight of milk of each patron for the previous day. This tends to prevent mistakes in recording the weights of milk for the day on which the milk is being received. The second advantage of the weigh sheet is that if a fair amount of pains is taken in keeping it, the sheet may be filed as part of the permanent records of the milk plant.

FILTRATION AND CLARIFICATION OF MILK

In a small-sized milk plant the milk is strained through wire gauze strainers or through cheese cloth and cotton filters, to remove insoluble dirt. In large milk plants the milk is pumped through specially constructed filters capable of handling large quantities of milk, or else it is passed through a clarifier which removes dirt by centrifugal force. This machine is built on the plan of a centrifugal separator, except that the internal device in the bowl is so constructed that it tends to prevent a separation of the fat from the rest of the milk. The sediment from the milk is deposited on the inside of the bowl of the clarifier, and if milk is extremely dirty, it sometimes becomes necessary to clean the bowl at quite frequent intervals as the machine will become clogged with slime.

As seen under the microscope a slide made from the slime taken from a clarifier bowl may contain dirt, bacteria, bits of casein, and leucocytes.

McInerney [109] gives the following analysis of 8 samples of clarifier slime:

Most investigators have found that clarified milk will give a higher bacteria count by the plate method than will unclarified milk. This is due to the fact that the process breaks up the colonies of bacteria into individuals. Sherman [110] working on milk of good sanitary

[109] McInerney, T. J., Clarification of Milk, Cornell Bulletin No. 389.
[110] Sherman, J. M., Some Bacteriological Tests of the Milk Clarifier, Journal of Dairy Science, Vol. I, No. 3.

Table 72.—Chemical Composition of Clarifier Slime.

Exp. No.	Per Cent Fat	Per Cent Water	Per Cent Total Solids	Per Cent Ash	Per Cent Nitrogen	Per Cent Casein
1	4.0	70.13	29.87	4.17	0.43	2.74
2	5.0	71.86	28.14	2.73	0.23	1.46
3	3.4	70.04	29.96	3.81	0.71	4.52
4	3.2	69.92	30.08	3.00	0.14	0.89
5	4.0	75.50	24.50	2.74	0.31	1.97
6	5.0	71.01	28.99	3.36	0.10	0.63
7	3.7	71.35	28.65	2.59	0.49	3.12
8	4.0	70.87	29.13	2.83	0.27	1.72
Average ...	4.0	71.33	28.67	3.15	0.33	2.13

quality, obtained increases in bacteria content per c.c. as shown in the following table. Two different makes of machines were used.

Table 73.—Effect of Clarification on the Bacterial Count of Milk.

Sample No.	Bacteria per Cubic Centimeter Before Clarification	After Clarification	Sample No.	Bacteria per Cubic Centimeter Before Clarification	After Clarification
1.....	3,700	6,100	13.....	3,300	5,600
2.....	3,800	6,300	14.....	5,900	7,300
3.....	5,500	8,500	15.....	9,300	13,800
4.....	2,900	6,300	16.....	4,800	7,600
5.....	4,200	6,200	17.....	1,800	3,100
6.....	4,100	6,200	18.....	2,500	3,300
7.....	3,400	7,400	19.....	2,900	3,700
8.....	3,900	6,100	20.....	11,400	13,400
9.....	3,400	4,900	21.....	4,300	6,400
10.....	3,000	4,900	22.....	3,600	4,500
11.....	3,200	6,800	23.....	10,300	13,400
12.....	4,300	9,600	24.....	7,800	9,300
Average for the 24 samples.....				4,720	7,112

In comparing the cream line which formed on clarified and unclarified milk, McInerney found that clarification reduced the cream line 2 to 3 per cent by volume.

Dahlberg [111] and Marquardt found that clarifying milk at 40° F. (4.4° C.) or below did not affect the cream line to any appreciable extent, but that temperatures above 40° F. did affect it.

These investigators compared the centrifugal clarifier with the milk filter and concluded that so far as the naked eye was concerned,

[111] Dahlberg, A. C., and Marquardt, J. C., Filtration and Clarification of Milk, N. Y. State Exp. Sta., Geneva, N. Y., Technical Bul. No. 104.

there was no difference in the efficiency of the two machines in removing visible dirt from milk. However, examination under the microscope revealed small particles of dirt in filtered milk, which were not present in clarified milk. Moreover, milk which was clarified the second time gave a scanty, pure white deposit on the inside of the bowl, whereas filtered milk when clarified gave a gray deposit, showing that the finer particles of dirt had not been removed by filtration. In no case did these investigators find that filtration, either by gravity or by force, affected the cream line in any way.

The location of a clarifier or filter will depend somewhat on the kind of machinery to which the milk is delivered. If a vat pasteurizer is used the clarifier or gravity filter may be located on an elevated platform so that the milk will flow directly to the pasteurizer, thus doing away with the necessity of a pump. If a continuous-flow pasteurizer is used, a milk pump will be used to force the milk through the pasteurizer, and an elevation for the clarifier or filter will be of no particular advantage.

PASTEURIZATION

The different methods of pasteurization have been discussed under grades of milk. The kind of machine used will depend to a large extent on the amount of milk to be handled. There are two main types of holder pasteurizers on the market. One consists of a well-insulated vat in which is a revolving coil, and the hot water used to heat the milk circulates through this coil. The hot water is stored either in a tank built into the vat, or else in a separate tank. The revolving coil causes the water to circulate from the tank through the coils and back to the tank again so that the flow is continuous. The exact principle which causes this flow is hard to explain, but is said by the manufacturers to be the same principle as that of the old Egyptian water mill.

Most of these pasteurizers are provided with an intake air valve, the proper regulation of which is necessary to cause the water to circulate through the coils into the supply tank. The milk in the vat should be brought to the pasteurizing temperature as quickly as possible, e.g., 142° F.-143° F., and then it should be held for the proper time, usually 30 minutes. While the milk is being held it is best not to run the coils any more than is necessary to maintain

the proper temperature, as violent agitation of milk while hot is said to prevent the cream from rising on it when it is bottled for market.

After heating the milk for the proper length of time, the hot water

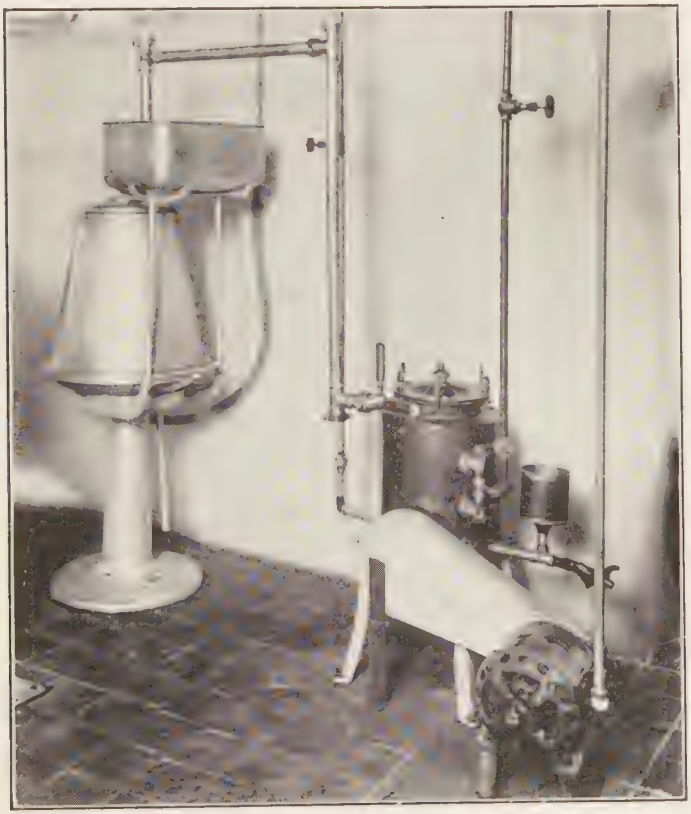


Fig. 43. Flash Pasteurizer Attached to Cooler.

may be drained from the supply tank and ice water, or brine and ice substituted, and the milk cooled to the desired temperature. This type of pasteurizer may be equipped with a set of brine coils, connected with the regular refrigeration system. The water which is used to cool the milk is then cooled by these brine coils; this method is the most satisfactory one. This type of pasteurizer has the ad-

vantage of being useful for a storage tank after the milk is heated and cooled. It is not as rapid as a continuous flow type but many large milk concerns install a battery of these pasteurizers and find them satisfactory. They are made to hold as high as 1000 gallons (about 8,600 lbs.) of milk.

Generally speaking the continuous flow, holder, types of pasteurizers consist of three parts: (1) the heater in which the milk is rapidly heated to the pasteurization temperature; (2) the holding tanks or vats; (3) the cooler.

The heaters and coolers are usually known as the internal tubular type and consist of a tube surrounded by a jacket. The milk circulates through the inner set of tubes and the heating or cooling medium, as the case may be, circulates in the space between the tubes and the outside wall of the jacket. Heating or cooling mediums may be forced through the coils by means of a pump, and in case of hot water for heating milk, some manufacturers make use of an ejector. Coolers are usually built in two sections, one of the sections being connected with the ordinary water supply which partially cools the milk, and the other section connected with the brine supply from the refrigerating system. This method conserves the brine supply and this reduces the cost of cooling. If large quantities of milk are handled one cooler may not be sufficient and in such cases a battery of coolers is employed, one or more being connected with the cold water system and one or more with the brine system. In cooling milk by means of brine in an internal tubular cooler, care must be taken not to freeze the milk in the tubes, as when once frozen it is very difficult to thaw out again.

The holding devices on continuous flow pasteurizers vary with different makes of machines, but they usually consist of a series of tanks or vats placed in a vertical or horizontal position. It is designed that the time required for a given amount of milk to flow through the series of vats or tanks will be sufficiently long to fulfil the requirements for pasteurization. This time is usually 30 minutes, and if a pasteurizer had two tanks, connected in series, it would require 15 minutes for the milk to flow through each tank. When tanks are supplied by a steam driven pump, care must be taken not to run the pump too fast, and thus force the milk through the tanks faster than is intended.

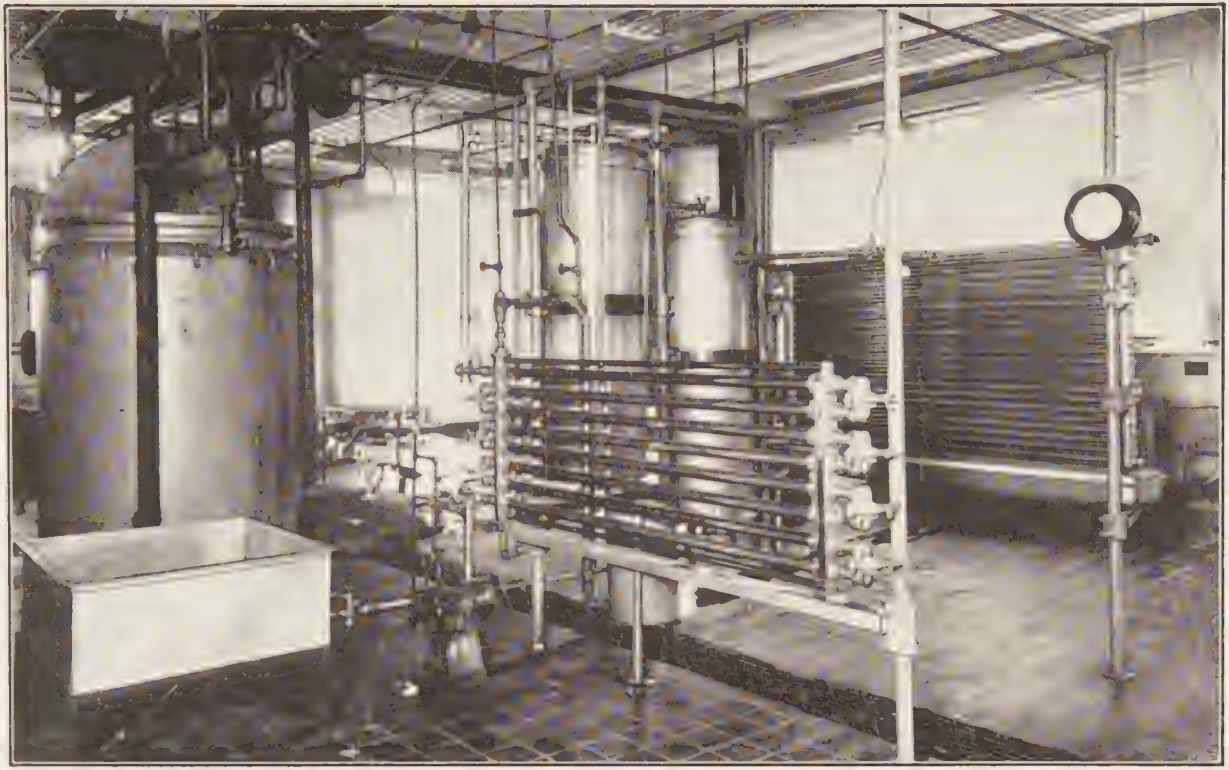


FIG. 44. Continuous Flow Pasteurizer with Upright Holding Tanks. This Apparatus is Also Equipped with a Partial Water Regenerative System

In other types of machines the flow of milk is controlled by a trip valve, which revolves at a slow rate of speed. The milk is held in each vat its proportionate share of the time required for pasteurization. If, for example, there are six tanks and the time of pasteurization is 30 minutes, the milk is held in each vat 5 minutes, and

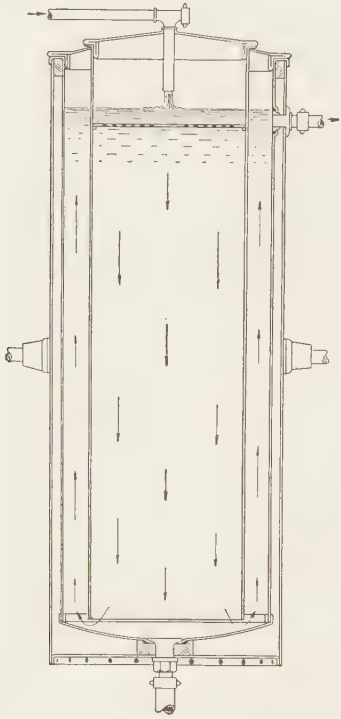


FIG. 45. Cross Section of Holding Tank to One Type of Continuous Flow Pasteurizer, Showing Course of Milk Through Tank. (Courtesy, D. H. Burrell & Co.)

it would require 5 minutes to fill a vat and 5 minutes to empty one. The tanks or vats are surrounded by a water jacket and this water is kept at a temperature which will hold the milk while it is passing through the machine, at the temperature of pasteurization.

The effect of temperature on the cream line has already been discussed, and this discussion shows the necessity of controlling the temperature within narrow limits. This is accomplished fairly well

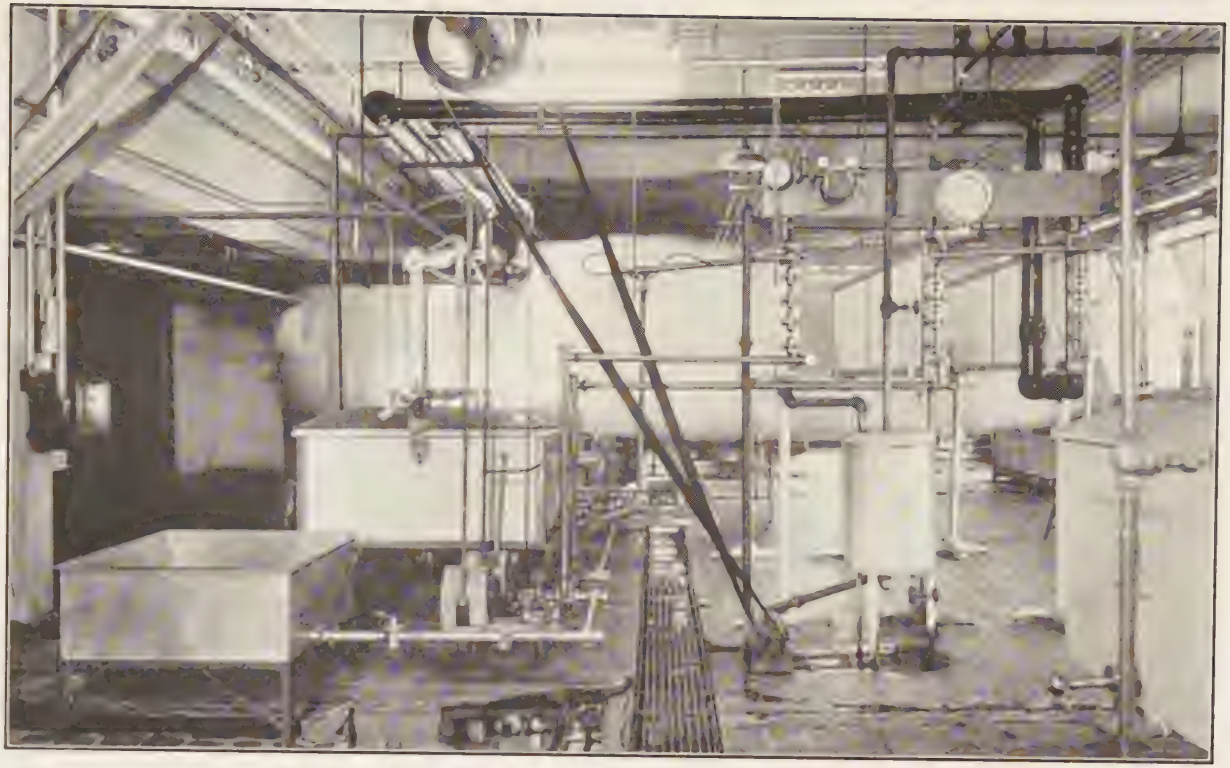


FIG. 46 Vat Type Holder Pasteurizer With Automatic Temperature Control

by constant observation and manipulation of the inlet steam valve, and with given conditions each day and a uniform boiler pressure the operator is able to control the temperature within quite reasonable limits.

The temperature of pasteurizers is frequently controlled by automatic temperature regulators, which are operated by compressed air. The air pump and compressed air tank may be a part of the pasteurizing unit, or may be separated from it, depending on the size of the tank. In this type of control, the heating medium (hot water) is heated by steam, which flows through a specially constructed valve, which is closed by a heavy spring. The steam valve is connected by means of a small pipe, with the compressed air tank, the valve being held open by the air pressure in the tank. The pipe containing the compressed air is provided with a relief valve, and this relief valve is connected with the milk which is being heated, by a pipe line filled with ether, which terminates in a thermometer bulb, inserted in the milk. If the temperature of the milk begins to rise above a fixed point, the ether in the tube expands, and this in turn exerts pressure on the relief valve, allowing the compressed air to escape. The steam valve is then closed by means of its spring and the steam supply is thereby shut off. When the milk begins to cool, and its temperature reaches a certain point, the ether in the tube contracts, allowing the relief valve on the compressed air line to close. The pressure on the compressed air line then increases and opens the steam valve, allowing steam to flow through the heating medium (hot water), and thus warm it up again. The relief valve on the compressed air line may be regulated to release the air pressure at any desired temperature.

Regardless of types or makes, a pasteurizer should fulfil certain requirements and these may be expressed as follows:

1. It should be efficient. By this is meant that it should do the work as represented. It should have no pockets or dead ends where milk will collect and not receive the proper heating.

2. It should be easy to clean and sterilize. All parts should be readily available for this purpose.

3. It should be simple in construction. The parts should not be so intricate and delicate that removing them for purposes of cleaning will cause them to deteriorate.

4. It should be economical in its operation. A pasteurizer should not require an undue amount of heating or cooling material or undue amount of power to drive it.

5. It should be safe from reinfection. All parts should be covered so that dust and dirt cannot blow into the milk.

FIG. 47. Glass Lined Milk Storage Tank, Equipped With Steam Heating and Brine Cooling Connections.

To pasteurize milk properly it is of course necessary to keep a constant record of the temperature of the milk as it leaves the

holding tanks. If a coil vat is used, the bulb of the thermometer should extend as far as possible into the mass of milk, so that the temperature indicated will be a true one of the entire mass. The best kind of thermometer for this purpose is the kind known as the recording thermometer (see upper right-hand corner, Fig. 46). This instrument is provided with a revolving dial covered with a removable paper chart, on which are lines indicating both time and tem-

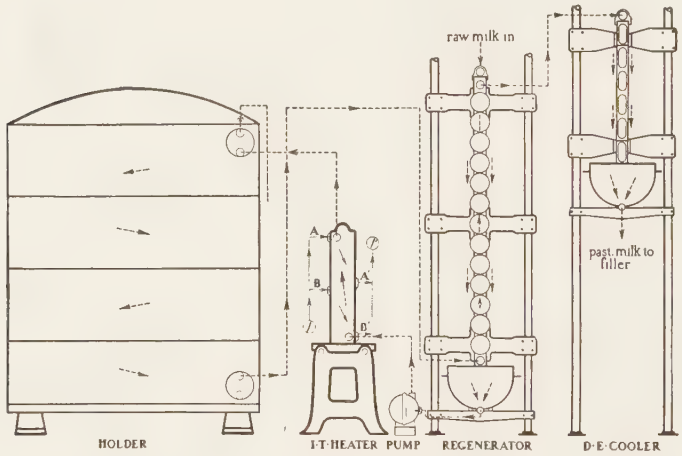


FIG. 48. Regenerative System of Pasteurization; Regeneration on Milk System; Raw Milk is Pumped Through I-T Heater, Then Passes Through Holder, Then Through Regenerator, and from Regenerator to D-E Cooler. Incoming Milk Passes Over Outside of Regenerator Tubes, Through Which Hot Pasteurized Milk is Flowing. In This Way Incoming Raw Milk is Warmed Before Going to Pasteurizer, and Pasteurized Milk is Partially Cooled Before Going to Cooler. (Courtesy, D. H. Burrell & Co.)

perature. The lines which follow the circumference of the dial indicate temperature, and those which radiate from the center indicate time. The dial is caused to revolve by means of clock works and a stilus moves toward or away from the center according to the temperature of the milk in which the bulb of the thermometer is immersed. In this way the length of time and temperature employed in pasteurization is accurately recorded. Some city boards of health require that these charts be filed away each day and kept where they may be inspected by representatives of the board of health.

The action of the stylus in recording thermometers depends on the expansion and contraction of a fluid in a small pipe connecting it with the bulb which is immersed in the milk. This pipe line should not be longer than is absolutely necessary as the fluid in it may be affected by the temperature of the air of the room, and in this way inaccurate temperatures would be secured by the stylus.

Some pasteurizers are operated on what is called the regenerative

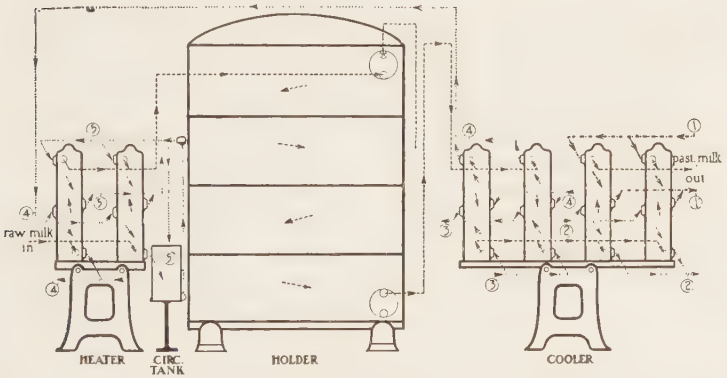


FIG. 49. Regenerative System of Pasteurization; Regeneration on Water System; Milk is Purveyed Through Internal Tubular Heater, and After Heating to Desired Temperature Passed Through Holder and Then Through Cooler. Water for Heating Starts from Calculating Tank (5″) and is Forced by Means of an Ejector Through a Section of the Heater (5-5″), Heating the Milk to the Desired Pasteurization Temperature. The Water Then Passes to Certain Sections of the Cooler (3-3′), and Since it is a Few Degrees Cooler Than the Milk from the Holder, it is Used to Cool Milk as Far as Possible. It is then Returned to the Heater and Used to Warm Up Incoming Raw Milk. The Water then Returns Again to Heating Tank (5″). (Courtesy, D. H. Burrell & Co.)

system. In this system the incoming milk to be pasteurized is made to pass through tubes of a section of the cooler. The hot milk from the pasteurizer passes over this cooler, and is partially cooled by cold milk and the cold milk is warmed before it enters the preheater of the pasteurizer. This saves heat in warming up the milk which is to be pasteurized and also saves refrigerating material in cooling the pasteurized milk.

Another system which is similar to the one described above is partially regenerative. The hot water used to heat the incoming

milk is passed through the tubes of one section of the cooler over which the pasteurized milk is flowing. While this water is quite hot, it is at the same time several degrees colder than the milk coming from the holding tanks of the pasteurizer. After passing through the cooler the water is again returned to the heating coils and partially warms up the incoming raw milk. The water then returns to the heater.

BOTTLING MILK

In nearly all market milk distribution, bottled milk has taken the place of dipped milk. In a very small market milk business, milk

FIG. 50. Rotary Type of Bottle Filler and Capper. Motor Driven.

is bottled by pouring from some container equipped with a spout, but if the business is of any size, a bottle filler of some kind is usually employed. Bottle fillers range in size from a small round tank

furnished with a single filler tube and lifted by hand from one bottle to another, to large automatic fillers and cappers, capable of filling and capping 60 to 70 bottles per minute. For a business handling about 300 quarts per day, the most desirable type of filler is that operated by hand levers and having five filler tubes on one side of the tank and four on the opposite side. In this type of filler the bottles are filled directly in the crates, a row of bottles being filled at one time, and the capping is done either by hand or with a small automatic hand capper.

In the largest and most rapid bottle fillers, the bottles are fed to the machine in a continuous stream, each bottle being filled by passing from one filler tube to the next, the last tube completing the process of filling the bottle. In this way no time is lost. Many of these fillers are of the rotary type in which the bottles, during the process of filling and capping travel in a circle.

In hand operated bottle fillers the milk is usually poured into the filler from cans. Care should be taken to keep the milk in the tank well mixed as it does not take long for the cream to rise and this would cause an uneven distribution of fat in the bottled milk. This same precaution should be observed in operating any filler, but it is not so liable to occur in the case of a large filler, as the milk is usually supplied in this case, in a continuous stream directly from the cooler connected with the pasteurizer.

In a large market milk business the milk is usually taken directly from the cooler connected with the pasteurizer, and the bottles are supplied in crates to the filler by means of a conveyor. When bottles are supplied to the filler in this manner, they are removed from the crates, fed to the machine and then after filling and capping are placed in the crates again. Large washers and sterilizers are on the market which deposit the clean and sterilized bottles directly onto an endless belt which delivers the bottle to the filler. In this case the bottle is not touched by the hand from the time it is placed in the washer until it leaves the machine, filled, capped and ready for market.

Some milk dealers inspect every bottle of milk as it comes from the filler and in this way aim to prevent dirty bottles or milk containing any sediment from finding its way into the channels of trade.

The filler tubes of all fillers are equipped with rubber gaskets and these soon become worn or cut and in this condition are very liable to leak milk. When the gasket, which comes in contact with the bottle, becomes cracked it is very difficult to clean and may become a source of contamination. For this reason they should be carefully watched and renewed as often as is necessary. Under ordinary

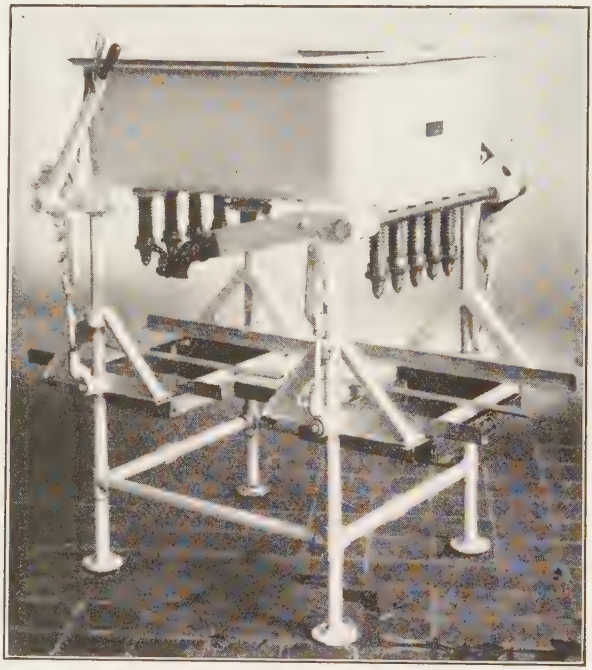


FIG. 51. Hand Bottle Filler. The Side with Four Filler Tubes is for Filling Quart Bottles; the Side with Five Tubes is for Filling Pint Bottles.

conditions the loss of milk in bottling is from 1 to 2 per cent and leaky gaskets will do much to increase this loss.

In most city milk plants the milk which is received on a certain day is pasteurized, cooled, and bottled and placed on the market the following day. In such a case the milk as it comes from the filler should be placed in cold storage as soon as possible. In a large plant brine-cooled rooms are usually provided for this purpose. In a small business, one of the most satisfactory ways of holding bottled

milk is to place the bottles in the regular crates and place cracked ice on them.

WASHING BOTTLES

It is very important that milk bottles be thoroughly washed and sterilized before milk is placed in them. Since milk is an excellent food for the sick many of the bottles may find their way into sick rooms where there are infectious, contagious diseases and in this way disease might be transmitted through milk. If it is known that milk is being delivered to a house where there is an infectious or contagious disease, it is best not to return any bottles from that house until the person suffering from the disease has fully recovered, and then all the bottles should be collected at one time. They should be placed in bags and should also be washed separate from the regular supply of bottles and special care should be taken in sterilizing them.

If the milk business is a small one, the bottles may be washed by hand, a long-handled bottle brush being used for the purpose. The bottles should be soaked in a warm water solution of washing powder, then washed and rinsed in clean warm water or hot water to remove all of the washing powder. If all of the washing powder is not removed, it gives a cloudy or streaked appearance to the bottle and naturally the customer thinks that the bottles are dirty. If no sterilizer is available to sterilize them by live steam, the bottles, after a careful rinsing, should be scalded for as long a time as possible in clean boiling water. This can be accomplished by placing them in a clean tank filled with water and turning live steam into the tank. Care must be taken, however, to see that the steam pipe does not blow boiler scale or rust into the tank and cause the bottles to become streaked.

In a moderate-sized market milk business, power-driven bottle brushes are in common use. These are driven in three different ways, namely: (1) by means of a steam turbine, (2) by means of a motor connected directly to the shaft to which the brush is attached, and (3) by means of a belt connected with a drive shaft. Some of these bottle washers consist of three brushes, placed closely together in a row, and are designed to wash two bottles at once. A bottle is placed

on each of the two outside brushes, and the outside of the two bottles is washed at the same time by the center brush.

In large market milk plants the so-called power rinsers and washers are used. In most of these machines the bottles are washed in the crates. The bottles are inverted and a device made of some non-rustable metal is fitted over the necks to hold the bottles in place.

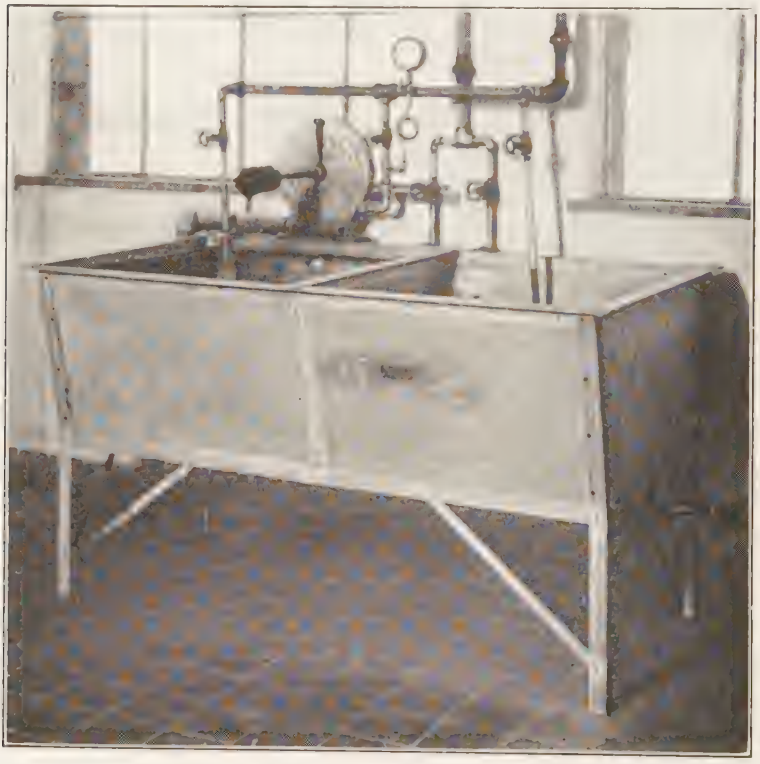


FIG. 52. Steam Turbine Single Brush Bottle Washer.

They are first subjected to a good rinsing with warm water and are next sprayed with a hot strong solution of some alkali powder. The crate is then moved automatically over jets of boiling water which rinses out the washing powder solution. Lastly, each bottle is subjected to the action of a steam jet in order to render it as near sterile as possible. After coming from the washer, the bottles should

be carefully inspected and any which are not clean should be set aside and washed with a rotary brush washer.

Another type of bottle washer than the one described above has already been mentioned in connection with filling bottles. In this type of filler the bottles are fed into a row of metal pockets which

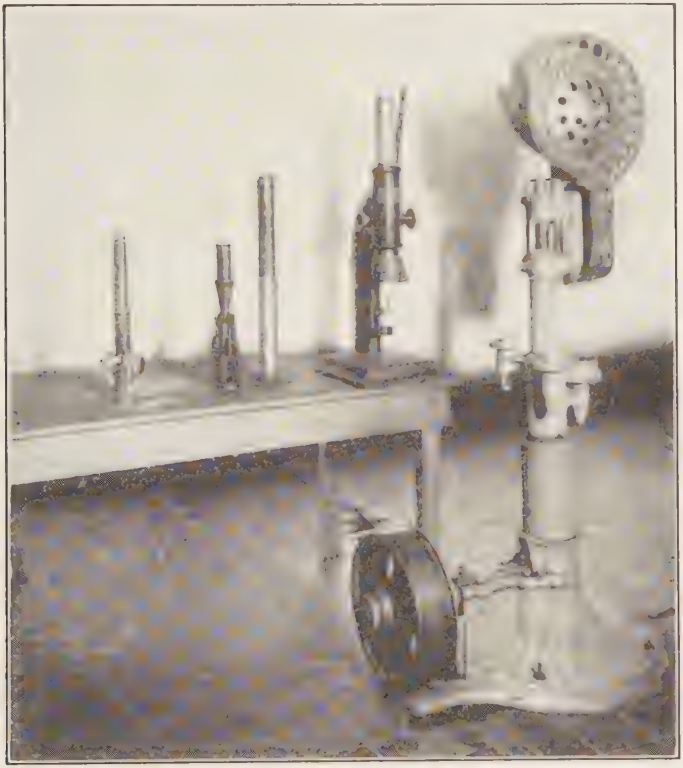


Fig. 53. Types of Bottle Cappers. Beginning at Left the Machines are: Anco for Inserting Ordinary Cap; Standard; Jam; Perfecto; Crown.

pass the bottles over a rinser, and then fit them on to a rapidly revolving brush. At the same time a strong washing powder solution is sprayed into the bottles and a brush also washes the outside. The bottles are then rinsed, steamed, and deposited on an endless belt which delivers them to the filler. This machine is a large one, weighing many tons, and is intended to be used only in large plants,

but where a large number of bottles are to be handled it is very efficient.

In cold weather bottles just returned from the route should not be washed until they have gradually become expanded by the warmer temperature. If an attempt is made to wash them while they are cold, there will be a big loss due to breakage.

If the bottles are not filled directly after washing they should be stored in an inverted position in a clean place free from contamination by dust or flies. They should never be placed in an upright position until placed under the bottle filler.

KEEPING RECORDS AND CHECKING LOSSES

In a book of this kind, it is impracticable to give details of methods of bookkeeping suitable for a city milk plant. In general the principles of bookkeeping which apply to any business may be applied to the market milk industry, but like all business, the market milk industry requires special forms and blanks to give the information desired. It should be mentioned in this connection, that while adequate records are necessary, the system of bookkeeping employed should not be so intricate that it requires a big overhead to keep it in operation. No record should be kept unless it has a distinct purpose, and care should be taken to see that the records kept show what is intended.

The following are some of the items which should be kept in a market milk plant:

1. Amount of milk received.

2. The amount of milk turned over to various departments, such as bottling, separating for manufacturing cream, and to manufacturing department, if any is carried on in connection with the market milk business.

3. The amount of product obtained, as this is the only basis for detecting losses.

4. The amount of product turned out to each person for the purposes of sale. This would include milk and cream checked out to route drivers.

5. The amount of product returned together with money received for sales or charge slips, when charge accounts are allowed.

6. The money paid for labor. If the plant is large, it may be

necessary to keep a separate account with different departments to determine whether or not they are a paying proposition.

7. Amount paid for supplies. If large quantities of a certain commodity are used, e.g., glass milk bottles, it may be desirable to keep separate accounts with these commodities.

One of the most perplexing problems in a market milk plant is the disposal of the surplus milk. No fixed rule can be stated for the disposition of this milk and what is done with it will depend to a large extent on the amount. There is always a question in regard to the advisability of a market milk plant engaging in dairy manufacturing and some boards of health will not allow dairy manufacturing to be carried on in the same rooms where milk is prepared for market. Some dealers keep the surplus milk as low as possible and sell it for what they can get. The manufacture of most dairy products calls for a large outlay of capital both in room and machinery, and enough manufacturing must be carried on to make such an outlay justifiable. The milk plant operator is sometimes obliged to buy more milk than he desires for his retail trade in order to control enough for his business and in such a case manufacturing becomes a necessity.

Local conditions will often determine the most profitable dairy product to manufacture. For example, there may be no ice cream plant in the vicinity and the surplus milk made into ice cream will bring a good return. Some milk dealers sour their surplus whole milk, churn it and get what butter they can and sell the buttermilk at a good price. The sale of the buttermilk works in nicely with the retail milk business, and the butter can almost always be sold at retail prices on the market milk route. However, it is usually poor business policy for a plant which is interested primarily in market milk to try and compete with a manufacturing plant in the manufacture of dairy products. The object of a market milk plant is to sell fluid milk and cream, and it should concentrate all its energies in that direction.

The milk plant operator must be constantly on the alert to prevent leaks and losses, as money saved by this means is just as good as money earned by selling more product. In a large plant the installation of a machine may sometimes take the place of enough labor to make such an installation profitable. In a certain milk plant the

use of a large automatic bottle washer which required a machinist and three helpers to operate, did work which formerly required several smaller machines and 8 to 10 operators. At the same time it should be definitely known before installing it that a certain machine will be profitable. It does not necessarily follow that every machine invented for a certain purpose will fulfil that purpose and one trouble experienced in the dairy industry has been the rapid advance in types of milk handling apparatus. This has necessitated large outlays of capital.

Enough labor should be employed to do the work thoroughly, yet at the same time care should be taken to see that each person is usefully employed. Oftentimes the fact that an employee does not accomplish as much as he should is the fault of the arrangement of his work rather than an indisposition on his part to do work. Work in a market milk plant differs from the work in many other types of manufacturing plants in that the same operation lasts for only a short time. To give the best and most profitable service in a market milk plant an employee should be skilled technically in several different dairy operations and to secure such service is difficult and costly. Some dairy plants find it more profitable to hire ordinary labor and then to employ technical men to supervise them. This method will work profitably only in a large plant, as an efficient technical man can, within reasonable limits, supervise several men as well as he can supervise a few men. Small plants sometimes make the mistake of employing too many high-priced supervisors and are at a loss to see why the system does not pay. The trouble is not with the men but lies in the fact that they have not enough to supervise to make their employment financially worth while.

The amount of milk handled by a milk plant is not an exact index of the number of men which should be employed in operating the plant. The following are some of the factors which influence the number of men employed in city milk plants:

1. Size of the plant. Usually a plant handling a large amount of milk will employ less help per unit of milk than will a small plant.

2. Kind of milk handled. A plant handling the very highest grades of milk, such as certified and grade A milk, will usually employ more help than one handling lower grades. One reason for this is

the fact that their milk commands a higher price and their trade is therefore more scattered. This is notably true of certified milk.

3. Distance from market.
4. Distance from railroad terminals.
5. Proportion of bulk milk handled to bottled milk handled.
6. Amount of cream produced and handled.
7. Amount of dairy products manufactured.

The following table [112] taken from United States Department of Agriculture Bulletin No. 973 gives a good idea of the number of employees required to operate plants handling various amounts of milk.

Table 74.—Number of Men Employed in Milk Plants Handling Various Amounts of Milk.

Gallons Milk Handled Daily	No. Plants	Plant Employees (Not Including Office Force) Average Number Gallons Handled Daily per Plant	Average Number Men per Plant	Average Number Gallons Handled per Man	Average Number Routes per Plant
Up to 100	4	85	1.0	85	1.0
101 to 250	18	168	1.7	98.8	2.4
251 to 500	31	390	2.8	139.2	4.4
501 to 1,000	35	788	5.7	138.2	9.8
1,001 to 1,500	15	1,303	7.2	180.9	12.4
1,501 to 2,000	11	1,745	11.5	151.7	20.5
2,001 to 3,000	12	2,621	14.6	179.5	25.4
3,001 to 5,000	16	3,921	20.5	191.2	37.9
5,001 to 10,000	7	7,357	32.7	224.9	62.6
Over 10,000	4	17,250	85.8	200.1	138.2

One of the most interesting facts shown in this table is the increase in number of gallons of milk handled per man in the large plants over the small plants. While this does not hold true in every case, yet it is true in most cases and it is a condition which might be expected.

MILK PLANT LOSSES

The loss or, as it is sometimes called, the shrinkage of milk in a plant is variable and oftentimes by care and proper supervision, it can be greatly reduced. According to United States Department of

[112] Clement, C. E., Milk Plant Operation, U. S. Dept. of Agriculture, Bull. 973.

Agriculture Bulletin 973, quoted above, the loss of milk in 115 plants varied from 0.3 per cent to 7 per cent with an average of 2.29 per cent.

Table 75 taken from above bulletin shows shrinkage in three city milk plants.

Table 75.—Shrinkage of Milk in City Milk Plants.

	Daily Receipts at Plants Gallons	Quantity Bottled Gallons	Daily Loss Gallons	Daily Loss Per Cent
Plant No. 1	1,221	1,184	37	3.0
	1,000	976	24	2.4
	1,200	1,162	38	3.2
	1,100	1,071	29	2.6
Average	1,130	1,098	32	2.8
Plant No. 2	1,324	1,299	25	1.9
	1,295	1,274	21	1.6
	1,492	1,468	24	1.6
	1,395	1,385	10	0.7
Average	1,376	1,356	20	1.4
Plant No. 3	1,049	1,004	45	4.3
	1,021	979	42	4.1
	1,087	1,046	41	3.8
Average	1,052	1,009	43	4.1

The following are some of the causes of milk losses: (1) Leaky cans, (2) leaky faucets, (3) leaky vats, (4) leaky pasteurizers, (5) inaccurate scales, (6) carelessness in weighing or measuring, (7) improper draining of cans, and this is especially true with cans containing cream, (8) improper draining of milk and cream bottles when they are dumped after returning from the route, (9) leaky gaskets on bottle fillers, (10) breaking of bottles of milk as in filling, (11) improper drainage of sanitary pipe, (12) inaccurate sampling and testing, (13) allowing products to sour due to lack of proper refrigeration, (14) inaccuracy in keeping records, and (15) losses due to inaccurate milk bottles.

Some states have laws in regard to the accuracy of milk bottles and all states should have such laws to protect both the dealer and consumer. In New York the law states that milk bottles shall be of the following sizes: Half gallon, three pints, one quart, one pint, one-half pint and one gill, full to the ring or stopple. The following

variations are allowed in the accuracy of milk bottles: Six drams above or below the ring or stopple on the half gallon; five drams above or below the ring or stopple on the three pint; four drams above or below the ring or stopple on the quart; three drams above or below the ring or stopple on pint; and two drams above or below the ring or stopple on the half pint and gill.

Chapter XX

THE TRANSPORTATION AND DISTRIBUTION OF MILK

The transportation of milk is important from two standpoints—the sanitary quality of the milk, and the cost involved. The sanitary quality is, of course, affected by the length of time the milk is on the road between the producer and consumer, the temperature at which it is held while being transported, and the protection afforded against contamination during transportation.

In our largest cities the cost of transportation is one of the biggest items of expense in getting milk from the producer to the consumer. Even in the smaller cities and villages transportation forms a large part of the overhead of local milk distributors, and it makes great inroads on the profits of the producer in getting his milk from the farm to the local milk plant. It is probably safe to say that the average city milk consumer thinks very little if at all of cost of transportation of the milk delivered daily to his home. It is, however, a question in which he should be vitally interested as it is the consumer who must pay for overhead charges, and he should be careful not to demand service which may be of questionable benefit and yet which may add to the cost of the distribution of milk. On account of differences in local conditions it is almost impossible to give definite costs which are of general value in regard to milk transportation and distribution. Freight rates on milk are definite and well established and these are usually worked out on a zone basis. A certain price per 100 pounds is charged for milk within a certain radius of a given receiving point and as the distance from this point is increased a proportionate increase in freight rate is required.

The freight rates on milk shipped in 40-quart cans to New York City from different zones is given in Table 76.

Considerable milk is also shipped to the city market in bottles. In Table 77 is given [113] the freight rates on bottled milk at various

[113] The data in Table 77 was kindly furnished by the New York Central Railroad.

Table 76.—Schedule of Freight Rates per 40-Quart Can for Milk Shipped to New York City, Under the Zone System.

Miles	Freight Rate Per 40-Qt. Can	Per 100 Lbs.	Miles	Freight Rate Per 40-Qt. Can	Per 100 Lbs.
10 or under	235	275	201–210	455	530
11– 20	245	285	211–220	470	545
21– 30	265	310	221–230	475	550
31– 40	275	320	231–240	480	560
41– 50	295	345	241–250	485	565
51– 60	305	355	251–260	500	580
61– 70	320	370	261–270	505	585
71– 80	330	385	271–280	510	595
81– 90	340	395	281–290	515	600
91–100	355	415	291–300	530	615
101–110	360	420	301–310	535	620
111–120	370	430	311–320	540	630
121–130	385	450	321–330	545	635
131–140	395	460	331–340	560	650
141–150	400	465	341–350	565	655
151–160	415	485	351–360	570	665
161–170	420	490	361–370	575	670
171–180	430	500	371–380	580	675
181–190	440	510	381–390	590	685
191–200	450	525	391–400	595	690

Table 77.—Freight Rates on Bottled Milk in 12-Quart Cases and 12-Pint Cases, at Different Distances from New York City—Less than Carload Lots.

Distance from New York	Rate in Cents per Case 12-Quart Case	12-Pint Case	Distance from New York	Rate in Cents per Case 12-Quart Case	12-Pint Case
40 or less	12	6½	230–240	20½	11½
40– 50	12	7	240–250	20½	12
50– 60	12½	7	250–260	21	12
60– 70	13	8	260–270	21	12
70– 80	14	8	270–280	21½	12½
80– 90	14½	8½	280–290	21½	12½
90–100	15	8½	290–300	22	12½
100–110	15	9	300–310	22	12½
110–120	15½	9	310–320	23	13
120–130	16	9	320–330	23	13
130–140	17	9½	330–340	23½	13
140–190	18½	11	340–350	24	14
190–200	18½	11	350–360	24	14
200–210	19	11	360–370	24	14
210–220	20	11½	370–380	24½	14
220–230	20	11½	380–390	24½	14½

distances from New York City. The figures given in the table are for bottled milk, both pints and quarts in 12 quart cases. Milk is shipped in other sized cases than those mentioned and definite freight rates are charged for these different sized cases. Other items of cost of transportation and delivery vary so widely in different localities that it is necessary to work out figures for each separate locality.

The problem of transporting milk from the farm of the producer to the receiving station is simple, when compared with other steps in milk transportation. As a general principle milk should be well cooled before starting on its journey to market. However, some companies accept milk without being cooled if it is delivered immediately after milking, and when the producer lives near the shipping station, this method works satisfactorily. The receiving station usually has better facilities for cooling and storing milk than has the average farm, and if milk is delivered as soon as the herd is milked, it is claimed that there will be less bacterial growth than if cooled at the farm and held there for several hours. This statement seems to be borne out in actual practice. The automobile truck has made it possible to deliver milk much more quickly than was formerly done when horses were employed and this is of great aid in getting milk from the farm to the receiving station in a short time. However, the auto truck has also made it possible to get milk from long distances from the receiving station so that, as a matter of fact, the bulk of a receiving station receipts may be on the road as long or even longer than before the advent of the automobile.

There also seems to be a growing tendency on the part of milk producers to hire their milk hauled, and this is especially true of those who are located at some distance from the receiving station. In such instances the milk is usually delivered at some central point where it is eventually picked up by the auto truck hired for the purpose. Frequently the milk stands at one of these collecting points for a long time without any protection from the hot rays of the sun. The same is also true at the receiving station itself. Many of the trucks, each carrying 30 to 50 cans of milk, arrive at about the same time, and each has to await its turn for unloading its cargo of milk. This means that some of the trucks must stand for two hours, or longer, before they can be unloaded, and unless special pains are taken to prevent it, the temperature of the milk in the cans will

rise to a temperature favorable for bacterial growth. The result is a milk of high bacterial content, and sometimes the producer is blamed for the poor quality of the milk when, as a matter of fact, he had no connection with it whatever.

Cans should always be protected from the sun by at least a canvas covering. Special jackets are manufactured for covering cans and when these are dipped in ice water they are very efficient in preventing a rise in the temperature of the milk. An experiment performed by the Dairy Division, United States Department of Agriculture,[114] shows very conclusively the effect of covering cans in preventing a rise in temperature. Cans of milk were hauled on a truck a distance of 13 miles and the time required was 1 hour and 35 minutes. The air temperature was 82.65° F. Some of the cans were uncovered, others covered with wet burlap and others with hair quilt jackets. All cans were 50° F. when the load started. The temperature of the milk in those cans which were uncovered rose 28½° F., those covered with wet burlap rose 8½° F., and those covered with a hair quilt jacket rose only 5½° F. This experiment also illustrates the value of cooling milk on the farm. While the rise in temperature of the milk in cans covered with a hair cloth jacket was only 5.5° F., if the milk had been cooled to only 60° F. when it started on its journey, the 5.5° F. rise would have been quite serious from the standpoint of a possible increase in bacteria count. When a partially filled can of milk is carried for a long distance over a rough road, the milk sometimes churns and globules of butter will appear on the surface. This trouble can sometimes be partially overcome by placing a flat wooden float on the surface of the milk. This trouble of milk churning during transportation is greatly increased by high temperatures, and this is an additional reason why milk should be cooled to a low temperature on the farm.

Milk either in cans or bottles should be covered to protect the containers from dust and dirt. Cans hauled over a dusty road will become covered with dust and while it may be difficult for this to find its way into the contents of the can it offers that possibility. Most can covers have a small hole in the top and if any water gets on to this cover, it may drip through this opening into the milk,

[114] Bowen, John T., The Application of Refrigeration to the Handling of Milk. U. S. Dept. of Agr., Bull. No. 98.

carrying the bacteria-laden dust with it. This question of covering milk during transportation is more serious in the case of milk bottles. The top of the milk bottle with its depression forms an easy place for the dust to collect. When the cap is removed, the dust is very liable to be poured into the container along with the milk.

In the vicinity of some of the larger cities considerable milk is picked up by local trains and carried to its destination in baggage cars. This milk is often left standing in the sun, on station platforms, until the arrival of the train. The baggage car, of course, has no refrigeration facilities, and by the time the milk has reached the city its temperature has risen considerably, and this rise in temperature means a corresponding increase in the number of bacteria per c.c. The effect on the temperature and bacterial count of milk due to carrying on unrefrigerated baggage cars is shown in Table 78.[115]

Table 78.—Temperature and Bacteria Count of Milk Carried in Baggage Cars, on Leaving the Country Shipping Station and on Arrival in the City.

Sample No.	Hours in Transit	Temp. of Milk, Degrees F.		Bacteria Count per c.c.	
		Leave Country	Arrive in City	Leave Country	Arrive in City
1	6½	63	70	2,010,000	3,030,000
2	6	64	72	360,000	380,000
3	5½	66	73	2,580,000	5,550,000
4	5½	68	73	1,810,000	4,440,000
5	6	69	70	230,000	1,600,000
6	6	65	70	210,000	1,370,000
7	6½	67	69½	170,000	2,400,000
8	6½	72	73	130,000	1,890,000
9	6	65	68	380,000	816,000
10	6	72	69	100,000	400,000
11	5½	68	68	1,950,000	3,450,000
12	5½	66	66	180,000	390,000
13	6	65	70	1,230,000	6,540,000
14	6	67	70	1,590,000	2,850,000
15	6	65	69	100,000	300,000
16	6	66	71	40,000	300,000

There are three main ways of refrigerating milk cars and one of them is to pile ice on top of the cans, breaking it sufficiently so that it will rest on the shoulders of the can as well as on the cover. Other cars have ice bunkers in each end and these bunkers are filled

[115] Fisher, R. C., Thesis, Influence of Transportation upon the Bacterial Content and Temperature of Milk and Summer Conditions, Cornell University, 1924.

through a trap door in the roof of the car. The more modern cars have a brine refrigerating system, which is very efficient in maintaining a low temperature. The cars are equipped with refrigerator doors to prevent the entrance of warm air. It should be borne in mind, however, that these refrigerator cars should not be depended upon to cool milk but that they are intended to hold milk to a low temperature after it has been cooled.

The latest and what promises to be the most successful milk car for transporting large amounts of milk long distances is the glass-lined tank car. This consists of a huge steel tank holding about 3,000 gallons, mounted on a railroad car. The tank is glass lined and is as thoroughly insulated as is possible. The jacket around the tank is equipped with brine coils which can be connected with the compression of the milk plant and the brine cooled to as low a temperature as desired. The milk is cooled to a low temperature before being placed in the tank and during long hauls there is almost no rise in temperature. The cars are filled and emptied by one of three different methods according to the location and convenience of the milk plant. These methods are (1) gravity, (2) milk pump, and (3) compressed air.

The cars have a further advantage in that they may serve as reservoirs for holding the milk until it is wanted within the plant itself.

The tanks, after washing, may be sterilized by turning live steam directly into them.

As an example of the efficiency of insulated glass-lined tanks in controlling the temperature of milk the results of an experiment, performed during the National Dairy Show of 1924, are very significant. Approximately 1300 gallons of milk were shipped in an insulated glass-lined tank mounted on an auto truck from Pittsburgh, Pa., to Milwaukee, Wis. The distance traveled was over 700 miles and the time consumed was about 60 hours. The temperature of the milk on leaving Pittsburgh was 36° F. and on arriving at Milwaukee it had risen to only 41° F., and the acidity was .127 per cent. The milk left Pittsburgh on Saturday and on the following Friday the temperature had risen only to 47° F. and the acidity was only 0.15 per cent. This test shows great possibilities for shipping market milk long distances in tanks of this sort.

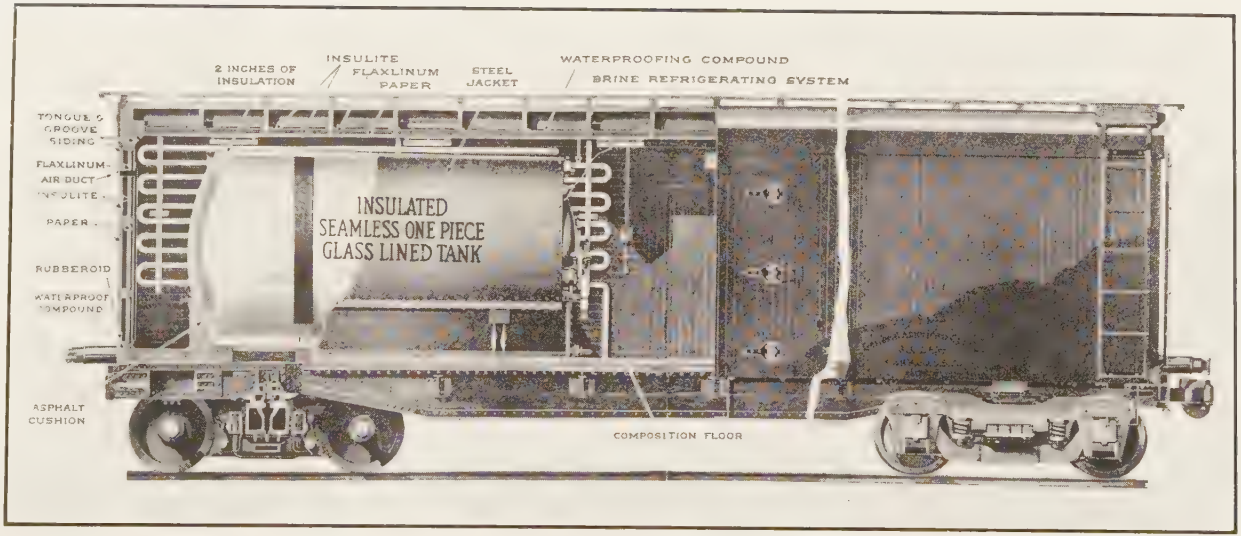


FIG. 54. Detailed Construction of a Glass-lined Refrigerator Milk Tank Car. (Courtesy, General American Car Co., Chicago, Ill.)

While some of the milk sold at retail is dipped, by far the larger amount is sold in bottles and nearly all of the milk sold in large cities is bottled milk. Selling milk in bottles has its advantages and disadvantages. The advantages are as follows:

1. The bottle holds an exact measure. This is advantageous not only to the consumer but also to the dealer. It is quite difficult to dip from a 40-quart can an exact amount, and in order to give good measure the delivery man is apt to dip a second time. This almost always results in giving over measure, and frequently not over 36 quarts will be dipped from a can which contained 40 quarts.

2. The cream is more evenly distributed in bottled milk than in dipped milk. Fat in milk rises to the surface very quickly and unless special precautions are taken those customers who are served from the bottom of the can will receive milk low in fat content.

3. Delivering milk in bottles is more sanitary than selling dipped milk. This advantage far outweighs all the disadvantages. In selling dipped milk the can has to be opened many times on the route and each time the can is opened it gives opportunity for dirt and dust to blow into it. There is also a chance that the dipper will become contaminated. It has already been pointed out, however, that the bottles should be properly protected during transportation.

4. If there is any sediment in milk, it will settle to the bottom of the bottle and this can be seen by the consumer. This fact tends to make the milk dealer careful to keep the milk free from insoluble dirt.

5. The use of milk bottles facilitates the keeping of records. It is much easier and more accurate to check out to a large number of drivers a certain amount of milk in bottles which are accurate than it would be to check out milk in cans which, while accurate, might not be quite full. The main advantage along this line, however, is in keeping record of milk returned and checking up losses. The exact amount of milk which can be dipped from a 40-quart can is so indefinite that it would be difficult to tell within 2 or 3 quarts whether milk lost on the route was due to dishonesty or due to a natural loss.

6. The shape of the milk bottle and the security of the seal makes it easier to refrigerate a bottle of milk than it would be to refrigerate milk placed in a pail or other similar container.

7. A glass bottle shows the cream line. If the customer does not see a good cream line, he makes a complaint and this is an incentive to the dealer in inducing him to handle milk containing at least a fair percentage of fat. It also makes him careful in pasteurizing his product, as it has already been pointed out that certain improper methods of pasteurization will prevent cream from rising on milk.

The disadvantages of using bottles may be summed up as follows:

1. They require a large initial outlay of capital, at the present time costing from about $5.25 to $8.75 per gross, depending on the size of the bottle and the number ordered.

2. There is a large loss of milk bottles in the market milk industry. This loss is due both to a normal breakage and also due to the fact that people use the bottles for household purposes, such as in the preserving of fruits. Consumers of milk are also sometimes very careless about returning empty milk bottles and throw them into the garbage can rather than wash and return them. This unfair practise is carried on to such an extent that in most cities there are one or more bottle exchanges. These concerns make it their business to collect from any place where they have been discarded milk bottles belonging to the various milk dealers and these are washed, sterilized, and returned to their rightful owners. The exchange charges a certain percentage of the value of the bottle for the work they do. Many households receive milk from more than one dealer and this means that the bottles belonging to one dealer will find their way into the plant of another dealer. These bottles are frequently returned to their rightful owner through the medium of the bottle exchange.

In some states there are very stringent laws, forbidding the use of milk bottles for any other purpose than for which they are intended and also forbidding the use of one dealer's bottles by another dealer.

The length of service of a milk bottle is expressed in the number of trips which a bottle will make and this is variable with different dealers, being usually from seven to twenty trips. The following table taken from United States Department of Agriculture Bulletin No. 973 (*loc. cit.*) gives some idea of milk bottle losses.

In order to cut down the loss of bottles the plan has been tried of making the customer pay for as many bottles as he takes per day and then make him produce the empty bottle or its equivalent in

Table 79.—Some Facts on Milk Bottle Losses.

Bottles Filled Daily	Number of Dealers Reporting	Average No. of Bottles Filled Daily	Average No. of Bottles Bought per Month	Proportion of Broken to Lost Bottles	Trips per Bottle
Up to 1,000.....	5	740	523	1: 0.8	21
1,001 to 2,000	7	1,685	1,114	1: 1.7	13
2,001 to 5,000	5	3,800	5,756	1: 2.5	14
5,001 to 10,000	16	7,906	9,446	1: 5.3	15
10,001 to 50,000	13	23,332	20,135	1: 8.8	17
Over 50,000	4	67,500	90,050	1:13.0	19

cash before selling him another bottle of milk. While this method has been carried out with some success in stores it does not lend itself very readily to the retail milk delivery. Unless all dealers will abide by it, the plan obviously will not work and it has been found very difficult to induce every dealer to stick to the plan.

The plan has also been tried of giving a premium to drivers if they returned a certain number of bottle per month from their route.

3. A third objection to delivery of milk in bottles is the weight. Milk bottles per gross weigh as follows:

Quarts	280 lbs.
Pints	170 lbs.
Half-pints	100 lbs.

4. The labor and expense of washing and sterilizing.

5. There is some danger, although it is remote, that bottles may be returned from sick rooms where there is some infectious contagious disease and the infection spread by means of contaminated bottles.

It is the last three objections to glass bottles that have caused interest in the paper milk bottle which was designed to be used once and then discarded. Up to the present time paper bottles have not been made which were durable enough for market milk trade and which were at the same time cheap enough in price to compete with the glass bottle.

Most of the paper milk bottles show neither the cream line nor the sediment which may have settled to the bottom of the bottle, and to this the customer objects.

One of the main objections which has been raised against the paper milk bottle in the market milk industry has been the large

number which must be kept in storage to supply the daily needs of a plant. The storage of the requisite number requires an immense amount of space. To do away with this difficulty the manufacturers have furnished these bottles to the dealer in knock down form and then rented machines for building them up. Up to the present time the dealer has not taken very kindly to this idea.

The cost of milk distribution in cities varies greatly under different conditions and to get actual costs it is necessary to make surveys covering each individual case.

The following items are some of the causes of these variations:

1. Size of load carried. The size of the load carried would, of course, depend on the size of the wagon or truck employed. In case of a farmer, peddling his own milk, and traveling a long distance over poor roads, a team is often advisable. However, for general city delivery one horse is sufficient and most economical. On a good road it is generally estimated that one horse can haul, for purposes of delivery, 300 quarts of bottled milk. In case an auto truck is used, the smaller trucks of three-quarters to one ton capacity are considered more economical than larger ones. It is, of course, desirable to have one man, especially if he is a good salesman, serve as many customers as possible. To accomplish this the drivers start out with as large a load as is practicable, and then a large truck or wagon is sent later to keep them supplied with milk instead of having them return to the plant for another load. This method is sometimes found to be especially desirable if routes are located at long distances from the main plant.

2. The distance traveled, and this would include both the time consumed in getting from the plant to the point where delivery actually begins, and the time consumed in delivering the milk. Probably this question of the distance traveled in delivering milk is one of the most important so far as cost is concerned. A great deal of study has been given to the question of the overlapping of milk routes with the idea of cutting down cost of delivery. It is this idea which is back of the plan of municipal milk supplies, where the milk would be mainly all of one grade, and there would be no particular incentive for consumers to take of different milk men. One section would be supplied by one deliveryman in so far as it was economical for him to cover the distance embraced in that

section. The distance traveled in delivering certified milk is one of the main factors in making the price of that grade of milk high. So few people take it and the demand is for such small units that the trade is very scattering, it being often necessary to travel a mile to deliver one pint of milk.

This fact is well illustrated in an investigation carried on in Massachusetts.[116] Two dealers delivered "Special" milk of extra sanitary quality and charged what was at that time a high price for it. Dealer No. 1 delivered only 7.45 quarts per mile and Dealer No. 2 only 5.86 quarts per mile although this latter figure included a small amount of cream. The significance of these figures is still more apparent when they are compared with 66 others distributors in the same series of investigations. These 66 distributors were divided into four groups on a basis of the cost of delivering a quart of milk and the smallest number of quarts delivered per mile by any one of these groups was 25.0 and the largest number 38.7.

Table 80.—Number of Times Each Mile of Street Is Covered in Delivering Milk in Five Cities in Wisconsin.

City	Total Number of Miles of City Streets	Total Number of Miles Traveled Daily Within City in Delivering Milk	Number of Times Each Mile of Street Is Covered
Milwaukee	602.63	3,440.28	5.71
Oshkosh	103.30	377.	3.75
Beloit	80.	213.54	2.67
Eau Claire	59.	142.5	2.42
Madison	81.	244.	3.01

In Table 80 is given the number of times each mile is covered in delivering milk in five cities of Wisconsin.[117] It will be seen that the variation was from approximately 2.5 to 5.7 times. This means a vast amount of lost energy and a big increase in cost of delivery.

3. The relative proportion between the bottled milk and bulk milk sold. It is obviously much easier and quicker and, therefore, cheaper to deliver bulk milk.

4. The location of the place where milk is delivered. If, for example, milk is delivered in a large tenement house where there are

[116] Cance, Alexander E., and Ferguson, Richard H., The Cost of Distributing Milk in Six Cities and Towns in Massachusetts, Mass. Agr. Exp. Sta., Bull. No. 173.

[117] Hubbard, B. H., and Erdmann, H. E., Marketing Wisconsin Milk, Wis. Exp. Sta., Bull. 285.

many flights of stairs to climb, the increased time required will increase the cost of distribution. Any place of delivery which is inaccessible will increase the cost of distribution very materially. In some instances an attempt has been made in a large tenement house to deliver the milk at some central point on the first floor. These attempts have never been successful because the customer demands service and some other dealer in order to secure business would deliver milk at the customer's door.

5. The condition of the road influences the cost of milk distribution. In the vicinity of large cities milk is now being transported to distributors long distances by auto truck. This means that good roads are necessary, especially in winter. If during the winter season or a part of it the roads are impassable for auto trucks and horses must be employed, the cost of transporting will be increased. If a city or village has poor streets or the streets are hilly, a longer time is consumed in delivering milk and this means increased cost.

6. The system employed is important in the cost of delivery. In connection with this question is involved the use of tickets. Tickets are usually sold in advance, at a price which gives the consumer a slight reduction in the cost of milk providing a certain number of tickets are purchased for cash. Some drivers are not allowed to leave milk unless they obtain either a ticket or cash for the milk. If the tickets are not available, the driver must spend time in securing them and this is expensive. If tickets are sold for cash in advance, their use is advisable, as they prevent the accumulation of poor accounts, but unless this is the case their disadvantages outweigh their advantages.

The advantages and disadvantages of using milk tickets may be summed up as follows:

Advantages:

1. Money for the product is secured in advance. This gives the dealer the use of the money and does away with poor accounts.

2. Requiring drivers to produce tickets for every unit of product sold tends to compel keeping accurate records.

3. Requiring drivers to turn in tickets instead of cash offers less opportunity and less temptation for dishonest people to keep pay for this product.

Disadvantages:

(1). If tickets are not put out for each day's milk, the deliveryman must spend time in getting them or else leave the customer without milk. If the latter course is followed, it is apt to incur the ill will of the consumer and customers are frequently lost in this way.

(2). Tickets left for milk are easily stolen. This often leads to serious misunderstanding between the dealer and customer.

(3). Tickets are usually placed by the customer inside the bottle. It is difficult to get them out and irresponsible drivers have been known to break bottles in order to get the tickets.

(4). Care must be taken to dispose of the tickets collected so that they cannot be stolen and used over again.

(5). If milk is sold for a different price during different months, customers may buy comparatively large amounts of tickets at the time when they are cheapest. The only way to avoid this is to limit the amount of tickets which may be purchased by each customer, basing this amount on their daily requirements. Another way is to use different colored tickets when a change in the price of milk is made.

6. The amount of milk delivered to each customer influences the cost of delivery. The larger the amounts the less the cost of delivery. While to a limited extent it is sometimes possible to increase the amount delivered to each customer, this factor is generally not within the control of the dealer. In this connection the relation of the number of pint bottles to quart bottles sold is important. It takes just as long and costs just as much to deliver a pint as it does a quart of milk, and if the consumer could be induced to use the extra pint of milk per day it would be advantageous to both customer and distributor.

7. The fact as to whether or not different dairy products are sold on the route influence cost of delivery. If, for example, butter and fancy cheese are handled, it will take much more time for the route man to make his rounds than if he is handling milk alone. The extra time used by the deliveryman in handling different dairy products is one of the factors which should be carefully considered before placing these products on the route with market milk.

8. Milk is frequently delivered at very early hours in the morning, in our large cities often starting at 2 A.M. How this time of delivery

affects cost of distribution, it is very difficult to say. It was probably started by the demands of consumers, who had the idea that if milk was delivered early it was fresh. There are two advantages to the practise; namely, the customer gets his milk in time to be used for breakfast and traffic is lighter during the earlier morning hours and it is easier for the delivery wagons to get about.

There are several disadvantages to the practise of such early delivery and the chief one is the difficulty in collecting bottles and obtaining tickets if the ticket system is used. If the deliverymen make collections, this is also difficult. In some cases the drivers do

FIG. 55. Neat and Attractive Milk Delivery Rig. This is a Good Advertisement for a Dairy Company. (Courtesy, Chestnut Farms Dairy.)

not attempt to gather bottles or make collections, a separate person being sent around for this purpose, later in the day. This, of course, greatly increases the cost of delivery. Cost of delivery is sometimes increased by using the wrong method of delivery, as for instance, trucks are used when horses would be cheaper, and vice versa. It seems to be the consensus of opinion that for short haul retail delivery, horses are more economical than trucks and that for long hauls trucks are cheaper than horses. However, so many factors enter into the question that each man must settle the question for himself. It should be pointed out in connection with this question that the possibility of using a truck after the milk on the route has been delivered is an important factor in deciding whether horses

or trucks are the most economical method of delivery. There is a very decided limit to the length of time a horse can be used each day, whereas the truck can be kept going constantly.

To give exact costs of retail milk delivery would be impossible as they vary in each individual case. Table 81 which includes 66 dealers, gives the retail delivery costs made in a certain survey [118] and while this data would not apply at the present time it shows the variations in delivery costs between dealers operating under very similar conditions.

Table 81.—Variation in Cost of Distribution Between 66 Different Dealers.

No. and Per Cent of Dealers	Cost of Distribution
4 or 6 per cent.....	Less than 1.5 cents.
14 or 21 per cent.....	Between 1.5 and 2.0 cents.
16 or 24 per cent.....	Between 2.1 and 2.5 cents.
13 or 20 per cent.....	Between 2.5 and 3.0 cents.
12 or 18 per cent.....	Between 3.0 and 3.5 cents.
7 or 11 per cent.....	Over 3.5 cents.

The authors of the above table point out the striking variation in cost of delivery between the different dealers and they also found the following facts to be true: First, that there was no correlation between cost of delivery and size of business. Dealers delivering 300 quarts or less and those delivering more than 1000 quarts are represented in each group excepting the first in the above table, Second, there was some correlation, although not a consistent one, between cost of delivery and quarts of milk retailed per mile of haul. Third, there was a close correlation between the number of customers per mile and the cost of distribution. The variation in costs of milk delivery is pointed out in a survey of the milk situation in Boston, made by the Boston Chamber of Commerce.[119] The results of this survey are printed in bulletin form and the following table taken from this bulletin shows very closely the distribution of costs of selling a quart of milk. It will be noted that delivery expenses amounted to 0.2926 cents, yet it is stated that in sparsely settled districts, the delivery costs amounted to as much as 3½ cents to 4 cents.

[118] Cance, A. E., and Ferguson, R. H., The Cost of Distributing Milk in Six Cities and Towns in Mass., Mass. Agr. Exp. Station, Bull. 173.

[119] The Milk Question in New England. Report of a Survey made by Boston Chamber of Commerce. (Data used by permission.)

Table 82.—Summary Selling Price and Unit Cost of the Average Quart Bottle of Milk, in City of Boston for Fiscal Year Ending March 30, 1917.

				Per Cent
Selling price			$.10421	100.00
Cost of fluid	$.04288			41.15
Waste	.0021			2.01
Cost of fluid content		$.04498		43.16
Country expenses		$.00401		3.85
Freight		$.00628		6.03
Factory overhead	$.00284			2.73
Pasteurization	.00081			.78
Cans, bottles, boxes, and caps	.00337			3.23
Bottling	.00267			2.56
Packing and icing	.00194			1.86
Manufacturing expenses		$.01163		11.16
General delivery expenses	$.00454			4.36
Stable expenses	.00651			6.25
Selling expenses	.01821			17.47
Delivery expenses		$.02926		28.09
Administrative expenses		$.00494		4.74
Total cost		$.10110		97.02
Net profit		$.00311		2.98
Total		$.10421	$.10421	100.00

In a survey made in Chicago [120] in 1917, the cost of delivering milk was shown by a careful investigation to be 3¼ cents per quart. Table 83 shows the cost of handling and distributing milk in the City of Chicago, as follows:

Pasteurization and cooling, per quart	$0.0030
Transportation from country, average	0.0050
Bottles, loss of, etc	0.0025
Refrigeration, icing, etc	0.0017
Cost of delivery	0.0325
Total	$0.0447

There has in recent years been much discussion, both from the lecture platform and through the press, in regard to advertising milk and dairy products. Dairymen have been accused of being poor

[120] Municipal Reference Bulletin No. 8, City of Chicago. Report on the More Economic Distribution and Delivery of Milk in the City of Chicago. (Used by permission.)

advertisers. Throughout the country there are many organizations of dairy interests representing the different lines of dairy work. Many of these have united to form a national or country-wide organization and these larger organizations have carried on quite an aggressive and effective advertising campaign regarding the food value of milk and dairy products. In the effort to bring about the use of more milk and dairy products in the diet, a vast amount of constructive work has been done by various colleges and experiment stations, schools of home economics, the federal and state governments, various research organizations and physicians.

In this campaign, the value of milk as a food has received its share of attention. The work has been carried on in various ways such as newspaper and magazine advertising, colored posters, charts giving facts and figures in regard to the healthfulness and comparative cost of milk with that of other foods. In this connection the necessity for sanitation in the production and handling of milk is frequently emphasized, and the dangers of impure milk are pointed out. Educational campaigns in regard to the necessity for clean milk are beneficial, but the mistake should not be made of leading the public to think that possible death lurks in every quart of milk. Frequently, milk dealers who sell pasteurized milk will advertise their product in such a way that the uninformed consumer might easily believe raw milk was poison. This is a mistake from the standpoint of the pasteurized milk dealer, for the consuming public will readily conclude that if raw milk is so dangerous it is unsafe to use even pasteurized milk.

At educational meetings of various kinds, milk bacteria are sometimes placed under the microscope and the public invited to look at them. Frequently the observers will remark that if milk contains such material they will use no more milk. Emphasizing the fact that milk always contains a few organisms and that certain types of bacteria are even beneficial is of no avail, and in such a case more harm is done than good. This is simply a case of over-emphasizing a point and placing a piece of information in the hands of people who do not know how to use it.

In order to increase sales, each milk dealer has to do a great deal of advertising with individual consumers. This is oftentimes best accomplished by a house-to-house canvass by a special representative

of the company and work of this kind is frequently carried on through the route drivers. Some companies give the deliverymen, in addition to their salary, a substantial bonus for each permanent customer which they serve.

One feature of good advertising is to have clean, attractive-looking delivery rigs, either wagons or trucks, and have the drivers of the rigs neatly dressed. If the delivery rig is dirty, it is naturally hard to convince the consumer that the milk does not suffer in quality from lack of care.

Chapter XXI

ILLUSTRATIVE PROBLEMS IN DAIRY INDUSTRY

There are many cases in dairy work where it is desirable and even necessary to have milk or cream contain an exact percentage of fat. Market milk may contain a percentage of fat lower than the demands of the trade will bear and cream is added to raise the fat content to a desired percentage. Market cream is usually sold on the basis of its fat content and in such a case the seller wishes to have the percentage of fat no more and the buyer wishes to have it not less than the percentage agreed upon. In the manufacture of many dairy products it is necessary to have a definite percentage of fat in the milk or cream used and this is true, both from the standpoint of the quality of the goods manufactured and from the standpoint of economy of manufacturing. This adjustment of the percentage of fat in milk or cream is called standardization. Standardization may be defined as raising or lowering the percentage of fat in milk or cream by the addition of milk or cream of a higher or lower fat content.

In some states the dairy laws distinctly forbid the addition of anything to whole milk or the taking away of anything from it if the milk is to be sold or offered for sale as market milk. Under such conditions the legality of adding cream to milk is questionable, even though the value of the milk is increased by the addition of cream. However, since milk is increased in value by having cream added to it, there has never been, so far as is known, any legal objection raised in regard to this practise.

Under the conditions mentioned above it would without doubt be considered illegal to reduce the fat content of whole milk by adding skim milk to it, since this would decrease the value of the whole milk and would in effect be the same as removing fat from it.

In dairy practise it is possible to obtain exactly the desired percentage of fat in milk or cream by standardization and in computing

the amounts of the different materials to be used it should always be kept in mind that there are two kinds of problems involved, one when the amount to be made up is definite and one where the amount is indefinite. Both of these conditions will be illustrated in the problems which follow.

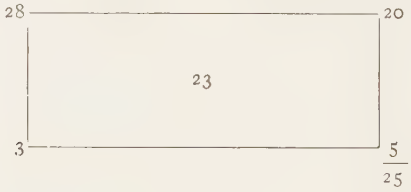
A method has been devised by R. A. Pearson which greatly simplifies the method of computing problems in standardization and is worked as follows: Draw a rectangle and place in the center of it the percentage of fat desired in the material to be standardized. On the left hand corners of the rectangle place the percentage of fat in the materials to be mixed. It is customary to place the larger number on the upper corner and the smaller number on the lower corner but these could be reversed without affecting the result of the problem. The smaller number on the left hand corner is then subtracted from the number in the center of the rectangle and the remainder placed on the diagonally opposite right hand corner. The number in the center of the rectangle is then subtracted from the larger number on the left hand corner and the remainder placed on the diagonally opposite right hand corner. The numbers on the right hand corners of the rectangle are the amounts of each material to be mixed and the percentage of fat in each one corresponds to the number on the left hand corner directly opposite. The sum of the numbers on the right corners of the rectangle will be a mixture containing the desired percentage of fat as expressed by the number in the center of the rectangle.

In the following problem the amount to be obtained by standardization is definite.

Problem No. I.

How much 3% milk and 28% cream will be required to make 500 lbs. of 23% cream?

Applying the directions given above we have the following results:



The interpretation of these results is that if 5 pounds of 3% milk were mixed with 20 pounds of 28% cream there would be obtained 25 pounds of a mixture testing 3%. According to the problem 500 pounds of the mixture are required and this is 20 times larger than 25 pounds, the amount obtained in the diagram ($500 \div 25 = 20$). Therefore if we multiply the numbers on the right hand corners of the rectangle by 20 we will have respectively the amounts of 28% cream and 3% milk required to make 500 pounds of a 23% mixture or 400 pounds of 28% cream and 100 pounds of 3% milk. ($20 \times 20 = 400$) ($5 \times 20 = 100$)

This problem may also be worked by simple proportion and if so worked the equations would be as follows:

$$5:25::x:500$$
$$25x = 2{,}500$$
$$x = 100,$$ the required number of lbs. of 3% milk

$$20:25::x:500$$
$$25x = 10{,}000$$
$$x = 400,$$ the required number of lbs. of 28% cream

Problems in standardization are easily proved and it is always best to prove them as this will tell whether or not the results obtained are correct. In the above problem the proof would be worked as follows:

500 pounds of 23% cream are desired and this amount of cream would contain 115 pounds of fat ($500 \times .23 = 115$). The question to be determined then is whether the amounts of 28% cream and 3% milk obtained by working the problem will furnish 115 pounds of fat.

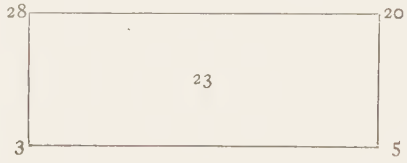
According to the results obtained there would be required 400 pounds of 28% cream and 100 pounds of 3% milk to make 500 pounds of 23% cream. 400 pounds of 28% cream will furnish 112 pounds of fat; ($400 \times .28 = 112$). 100 pounds of 3% milk will furnish 3 pounds of fat; ($100 \times .03 = 3$). $112 + 3 = 115$ pounds of fat which is the desired amount and proves that the problem is worked correctly. While proving the problem will point out whether or not a mistake has been made, it will not point out the location of the error.

Problem No. II.

The following problem is an illustration of the method used when the amount to be made is indefinite.

How much 3% milk must be added to 500 pounds of 28% cream to make a mixture testing 23%?

Following the directions previously given we obtain the following results:



These results show that for every 20 pounds of 28% cream used there must be added to it 5 pounds of 3% milk. According to the problem 500 pounds of 28% cream must be used and this is 25 times larger than the amount of 28% cream indicated on the upper right hand corner of the rectangle ($500 \div 20 = 25$). In other words, to satisfy the requirements stated in the problem we must use 25 times as much 28% cream as shown on the upper right hand corner of the rectangle. The 28% cream and the 3% milk must, however, be kept in the proportion of 20 pounds of the former to 5 pounds of the latter, so if we increase the amount of 28% cream 25 times we must increase the 3% milk 25 times.

This will give 500 pounds of 28% cream ($20 \times 25 = 500$) and 125 pounds of 3% milk ($5 \times 25 = 125$). The sum of these equals 625 pounds of a mixture testing 23% ($500 \div 125 = 625$).

Using simple proportion to work problem No. 2 the equation would be as follows:

$$5 : 20 :: x : 500$$
$$20x = 2500$$
$$x = 125 \text{ pounds of 3\% milk}$$

Proof. Problem No. 2.

625 pounds of cream testing 23% fat would contain 143.75 pounds of fat ($624 \times .23 = 143.75$). The 625 pounds of cream were made by adding 500 pounds of 28% cream and 125 pounds of 3% milk. 500 pounds of 28% cream will contain 140 pounds of fat

($500 \times .28 = 140$). 125 pounds of 3% milk will contain 3.75 pounds fat. ($125 \times .03 = 3.75$) $140 + 3.75 = 143.75$ pounds of fat which is the desired amount and proves that the problem is correct.

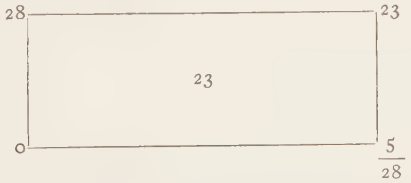
The rectangle method of computing problems in standardization may be utilized when skimmilk is used as one of the ingredients of the mixture. While there is a slight amount of fat in skimmilk the amount is so small that it will not affect the results and for this reason the test of the skimmilk is considered zero.

The following problem in which the amount to be made up is definite illustrate the use of the rectangle method when skimmilk is used as one of the materials to be mixed.

Problem No. III.

How much 28% cream and how much skimmilk will be required to make 500 pounds of a cream testing 23%?

Following the directions already given in Problem No. I we obtain the following results:



These figures in the right hand corners of the rectangle show that it would require 5 pounds of skimmilk to every 23 pounds of 28% cream to make 28 pounds of a mixture testing 23% fat. We desire however 500 pounds or an amount which is 17.85 + times as large as the amount obtained in the diagram ($500 \div 28 = 17.85$). We would therefore have to multiply both the 23 and the 5 by 17.85 to obtain respectively the amount of 28% cream and skimmilk necessary to make 500 pounds of 23% cream ($17.85 \times 23 = 410.55$), and 89.25 pounds of skimmilk ($17.85 \times 5 = 89.25$). The 89.25 added to the 410.55 gives 499.80 pounds, which lacks .2 of a pound of the 500 pounds desired. This discrepancy is caused by the fact that 28 is not contained in 500 pounds an even number of times.

A simple proportion could of course be used to find the desired

amount of 28% cream and skimmilk. These proportions would be as follows:

$$23:28::x:500$$
$$28x = 11{,}500$$
$$x = 410.71 \text{ pounds of } 28\% \text{ cream}$$
$$5:28::x:500$$
$$28x = 2{,}500$$
$$x = 89.28 \text{ pounds of skim milk}$$

In the following problem, where skimmilk is one of the ingredients used, the amount to be made up is indefinite.

Problem No. IV.

How much skimmilk must be added to 500 pounds of 28% cream to make a mixture testing 23%?

Following the directions given under Problem No. II the rectangle method gives the following results:

The figures on the right of the rectangle show us that it will take respectively 5 pounds of skimmilk and 23 pounds of 28% cream to make a mixture testing 23%. We therefore have the following simple proportion:

$$5:23::x:500$$
$$23x = 2500$$
$$x = 108.69+ \text{ pounds of skim milk}$$

If this 108.69 pounds of skimmilk is added to the 500 pounds of 28% cream the result will be 608.69 pounds of cream testing 23% fat.

When skimmilk is used as one of the ingredients of a mixture, problems in standardization may be worked by percentage as easily as by any other method. The same conditions expressed in Problem No. III will illustrate standardization by percentage, when the amount to be made up is definite.

Problem No. V.

How much 28% cream and how much skimmilk will be required to make 500 pounds of a 23% cream?

The 500 pounds of 23% cream when made up will contain 115 pounds of fat ($500 \times .23 = 115$). Since the skimmilk contains no fat, all of the 115 pounds of fat must be furnished by the 28% cream. The problem then is to find how much 28% cream will be necessary to furnish 115 pounds of fat; and this is done by dividing 115 by .28 which gives 410.71 + pounds ($115 \div .28 = 410.71+$). If in the 500 pounds of the mixture 410.71 pounds is 28% cream, the rest would necessarily be skimmilk, so by subtracting 410.71 from 500 we obtain 89.29 pounds of skimmilk ($500 - 410.71 = 89.29$). The conditions expressed in Problem No. IV will illustrate standardization by the percentage method, when skimmilk is used as one of the ingredients when the amount to be made up is indefinite.

Problem No. VI.

How much skimmilk must be added to 500 pounds of 28% cream to make a mixture testing 23%?

Since the skimmilk furnishes no fat and the 500 pounds of 28% cream is used there must be in the mixture when made up 140 pounds of fat ($.28 \times 500 = 140$). The 140 pounds of fat will be in a mixture testing 23%. Therefore there would be as many pounds of the mixture as .23 is contained into 140 or 608.69 pounds ($140 \div .23 = 608.69$). The difference between 608.69 and 500 will give 108.69 which is the number of pounds of skim milk in the mixture testing 23%. It will be noted that working problems like Nos. IV and V by the percentage method is, in reality, working the proof of the same problem when worked by the rectangle method.

Problems in standardization may be computed on a one pound basis. The results thus obtained may then be used in a simple proportion to find the amounts of different materials necessary to make any quantity of a mixture of a desired fat content.

The same condition as those stated in Problem I. will show this method of computation and will make it easy to compare this method with the one in which the rectangle is used.

Problem No. VII.

How much 28% cream and 3% milk will be required to make 500 pounds of a 23% cream?

One pound of 28% cream contains.....	.28 pounds of fat
One pound of 3% milk contains	.03 pounds of fat
The difference is.....	.25 pounds of fat
One pound of 28% cream contains.....	.28 pounds of fat
One pound of 23% cream contains.....	.23 pounds of fat
The difference is	.05 pounds of fat

The 3% milk may properly be regarded as a reducing agent to lower the fat content of the 28% cream to 23% and every time one pound of 3% milk is substituted for one pound of 28% cream the fat content of one pound of the mixture is reduced .25 of a pound. It is desired to reduce the fat content of one pound of the mixture .05 of a pound. The question then resolves itself into how much 3% milk would be required to reduce a pound of the mixture .05 of a pound of fat or in other words to reduce a pound of the mixture to 23% fat. It would take as much 3% milk as .25 pounds of fat is contained into .05 pounds of fat or .2 pounds of 3% milk ($.05 \div .25 = .2$). The remainder of the pound of the mixture would consist of .8 pounds of 28% cream ($1.0 - .2 = .8$). To find the amount of 3% milk which would be required in a 500 pound mixture testing 23% we would use the following simple proportion:

1:.2:: 500:x
x = 100 pounds of 3% milk

By subtracting the 100 pounds of 3% milk from the 500 pound mixture we obtain 400 pounds of 28% cream ($500 - 100 = 400$) or another simple proportion could be formed as follows:

1:.8:: 500:x
x = 400 pounds 28% cream

The proof of this problem is the same as given under Problem No. I.

The computations necessary to use in this method when the amount to be made up is indefinite may be well illustrated by the example used in Problem No. II.

Problem No. VIII.

How much 3% milk must be added to 500 pounds of a 28% cream to make a mixture testing 23%?

One pound of 28% cream contains.....	.28 pounds of fat
One pound of 3% milk contains	.03 pounds of fat
The difference is.....	.25 pounds of fat
One pound of 28% cream contains.....	.28 pounds of fat
One pound of 23% cream contains.....	.23 pounds of fat
The difference is	.05 pounds of fat

The 3% milk may, the same as in Problem No. VII, be regarded as a reducing agent and the same method of reasoning is employed as was used in Problem No. VII to find the amount of 3% milk there would be in one pound of a mixture testing 23% fat.

We find that this is .2 of a pound ($.05 \div .25 = .2$). .8 pound of the one pound mixture would consist of 28% cream ($1 - .2 = .8$). By using these figures in a simple proportion the amount of 3% milk necessary to add to the 500 pounds of 28% cream may readily be computed.

The proportion is as follows:

$$.2 : .8 :: x : 500$$
$$.8x = 100.0$$
$$x = 125 \text{ pounds of } 3\% \text{ milk}$$

The proof of this problem is the same as that given under Problem No. II.

CHANGING QUARTS TO POUNDS AND POUNDS TO QUARTS

Frequently in dairy work it is necessary to change quarts of milk or cream to pounds and vice versa. Milk of course varies greatly in fat content but the percentage of fat in milk is comparatively small when the entire milk content is considered. For this reason the weight of a quart of milk is not appreciably affected by normal variations in percentage of fat, and the weight of a quart of normal milk is usually considered to be 2.15 pounds.

When the amount of milk is expressed in quarts the number of pounds is obtained by multiplying the number of quarts by 2.15.

Problem No. IX.

How many pounds of milk would there be in a tank holding 500 gallons?

One quart of milk weighs 2.15 pounds therefore one gallon would weigh 8.6 pounds ($4 \times 2.15 = 8.6$). 500 gallons would weigh 8.6 times 500 or 4300 pounds.

The number of quarts of milk may be obtained by dividing the number of pounds of milk by 2.15.

Problem No. X.

How many quarts of milk would be contained in a vat holding 5000 pounds?

Since one quart of milk weighs 2.15 pounds a vat holding 5000 pounds of milk would contain as many quarts as 2.15 is contained in 5000 or 2325.58 quarts ($5000 \div 2.15 = 2325.58$).

Fat is present in cream in sufficient amount to cause a variation in weight in a given volume of cream testing different percentages of fat. On this account it is necessary to know the percentage of fat in any given sample of cream and the weight of a given volume of the sample before it can be converted from quarts to pounds or pounds to quarts.

Below is given a table showing the weight of a quart of cream containing different percentages of fat.[121]

Table 83.—Showing Weight of a Quart of Cream Containing Different Percentage of Fat.

Percentage of Fat	Weight of One Quart of Cream in Pounds
20	2.115
25	2.100
30	2.088
40	2.055
50	2.028

The method of converting quarts of cream to pounds or pounds of cream to quarts is the same as that already given for milk and needs no special explanation.

COMPUTING THE AMOUNT OF MILK NECESSARY TO FURNISH A GIVEN AMOUNT OF CREAM

In order to find the amount of milk necessary to furnish a given amount of cream it is necessary to know the percentage of fat in the milk used and in the cream which is to be produced. A specific problem will illustrate the method of computation.

[121] Cornell Reading Course Bulletin No. 98.

Problem No. XI.

How many pounds of 4% milk will be required to furnish 150 pounds of 32% cream?

The 150 pounds of 32% cream will contain 48 pounds of fat ($.32 \times 150 = 48$). The 48 pounds of fat must be supplied by the 4% milk and it will take as much 4% milk as .04 is contained in 48 or 1200 pounds of 4% milk ($48 \div .04 = 1200$).

It is sometimes desirable to compute the number of pounds of milk which a certain vat will hold. This is especially desirable in deciding the size of a vat it is necessary to order for certain purposes. Oftentimes the dimensions of a vat will be determined by the space it must occupy when in position for use. To determine the weight of milk which any vat will hold it is necessary to find the cubic contents of the vat and in case the vat is rectangular in shape this is done by multiplying its length by its width by its depth. The cubic contents expressed in terms of cubic feet is then multiplied by 64.5 which is the average weight of one cubic foot of normal milk.

Problem No. XII.

How many pounds of milk will be contained in a vat 12 feet long, 3 feet wide and 1.5 feet deep?

$3 \times 12 \times 1.5 = 54$ cubic feet contained in the vat. Since one cubic foot of normal milk weighs 64.5 pounds, 54 cubic feet would weigh 54×64.5 which equals 3483 pounds ($54 \times 64.5 = 3483$).

In case the milk vat is cylindrical instead of rectangular in shape the cubical content is obtained by multiplying the area of the base by the height. If the vat is intended to hold skim milk instead of whole milk, the number of cubic feet in the vat should be multiplied by 64.8 instead of 64.5. This is because skim milk has a higher specific gravity than whole milk.

DETERMINING THE PRICE CHARGED FOR CREAM

On account of the many factors involved in the production of market cream it is sometimes difficult to determine the price which should be asked for it. One method which is quite satisfactory is to base the price of cream of a certain fat content by comparing it with the price of market milk of a certain fat content.

Problem No. XIII.

If market milk containing 4% fat is selling for 12c per quart, how much should be asked for market cream per quart, the cream containing 32% fat?

One unit of the milk contains 4% fat, and one unit of the cream contains 32% fat. The cream contains therefore 8 times as much fat as the milk ($32 \div 8 = 4$). Based on its fat content the cream should therefore be worth 8 times what the milk is worth or 96¢ per quart ($8 \times 12 = 96$). While it is true that the skim milk is left after the cream has been obtained by separating the milk, yet the loss due to separation and bottling is considerable and the value of the skim milk is in many cases regarded as only a legitimate means of making good these losses.

FINDING THE AVERAGE TEST OF DIFFERENT WEIGHTS OF MILK CONTAINING DIFFERENT PERCENTAGES OF FAT

To determine the average percentage of fat in two or more amounts of milk, testing different percentages of fat, it is necessary to divide the total amount of fat by the total amount of milk and multiply the quotient by 100. To get the total amount of fat it is of course necessary to multiply each lot of milk by the percentage of fat it contains and then these results are added together.

It is incorrect to add the different percentages of fat and then divide the sum by the number of tests added. The following problem illustrates the correct method of working examples of this sort.

Problem No. XIV.

What is the average percentage of fat in the following amounts of milk?

500	pounds	testing	3.8%	contains	21.0	pounds	fat
850	"	"	3.8%	"	32.3	"	"
900	"	"	4.1%	"	36.9	"	"
1000	"	"	3.0%	"	30.0	"	"
400	"	"	5.0%	"	20.0	"	"
2000	"	"	4.0%	"	80.0	"	"
1200	"	"	3.4%	"	40.8	"	"
1500	"	"	5.1%	"	76.5	"	"
8350	total pounds of milk				337.5	total pounds fat	

$337.5 \div 8350 = 4.04\%$ average test.

AMOUNT OF MILK NECESSARY TO MAKE A GIVEN AMOUNT OF CREAM

In producing market cream it is sometimes necessary to know the amount of milk required to yield a given amount of cream. To compute this amount it is necessary to know the percentage of fat in both the milk and the cream since the problem is worked on a fat basis.

Problem No. XV.

How much milk testing 4% fat will be required to make one quart of cream testing 30% fat?

One quart of 30% cream weighs 2.088 pounds and would contain .6264 lbs. of fat ($2.088 \times .30 = .6264$). It would require as many pounds of 4% milk to furnish the 2.088 pounds of 30% cream containing .6264 pounds of fat as .04 is contained in .6264 or 15.66 ($.6264 \div .04 = 15.66$). Since one quart of milk weighs 2.15 pounds, 15.66 pounds would equal 7.28 + quarts ($15.66 \div 2.15 = 7.28+$).

CHANGING BOARD OF HEALTH LACTOMETER READINGS TO QUEVENNE LACTOMETER READINGS

Problem No. XVI.

If the Board of Health lactometer reading of a sample of milk was 112, what would be the equivalent Quevenne reading?

One degree Board of Health is equivalent to .29 of a degree Quevenne. Therefore 112 Board of Health degrees would equal .29 times 112 or 32.48 degrees Quevenne ($112 \times .29 = 32.48$).

CHANGING QUEVENNE LACTOMETER READINGS TO BOARD OF HEALTH LACTOMETER READINGS

Problem No. XVII.

If the Quevenne lactometer reading of a sample of milk was 32.5 what would be the equivalent Board of Health reading?

.29 of a degree Quevenne is equal to 1 degree Board of Health. Therefore 32.5 Quevenne degrees would be equivalent to as many Board of Health degrees as .29 is contained into 32.5 or 112.06 + ($32.5 \div .29 = 112.06+$).

Problem No. XVIII.

This problem illustrates the method of correcting for temperature on the Quevenne lactometer when the temperature of the milk is below 60° F. Since the temperature of the milk is below 60° F. the

density of the milk is greater than it should be to give a correct reading and for this reason the correction factor (.1 of a lactometer degree for every degree in temperature below 60° F.) should be subtracted from the reading indicated by the lactometer.

What would be the true reading of a sample of milk which gave a Quevenne lactometer reading of 31.0 at 55° F.?

Since the instrument is graduated to be used at a temperature of 60° F., the sample is 5° F. colder than it should be to give a correct reading (60 — 55 =5). The correction factor is .1 of a lactometer degree for every degree in temperature below 60° F., and for 5 degrees it would be .5 of a lactometer degree (5 × .1 = .5). 31 — .5 = 30.5, the true lactometer reading. In this instance the true specific gravity would be 1.0305.

Problem No. XIX.

This problem illustrates the method of correcting for temperature on the Quevenne lactometer when the temperature of the milk is above 60° F. It will be noted that since the temperature is above 60° F., the density of the milk is less than it should be and therefore the correction factor (.1 of a lactometer degree for every degree in temperature above 60° F.) is added to the reading indicated by the lactometer.

What would be the true reading of a sample of milk which gave a Quevenne lactometer reading of 31.0 at a temperature of 66° F.? Since the instrument is graduated to be read at a temperature of 60° F. the sample is 6° F. warmer than it should be to give a correct reading (66 — 60 = 6). The correction factor is .1 of a lactometer degree for every degree in temperature above 60° F. and for 6° F. above it would be .6 of a lactometer degree (6 × .1 = .6). 31 + .6 = 31.6, the true lactometer reading. In this case the true specific gravity would be 1.0316.

Problem No. XX.

This problem illustrates the method of correction for temperature on the Board of Health lactometer when the temperature of the milk is above 60° F. It will be noted that since the temperature of the milk is above 60° F. the density of the milk is less than it should be, and therefore the correction factor (.3 of a lactometer degree for every degree in temperature above 60° F.) is added to the reading indicated by the lactometer.

What would be the true reading of a sample of milk which gave a Board of Health reading of 110 at a temperature of 67° F.?

Since the instrument is graduated to be used at a temperature of 60° F., the sample is 7° F. warmer than it should be to give a correct reading ($67 - 60 = 7$). The correction factor is .3 of a lactometer degree for every degree above 60° F. and for 7° F. above it would be 2.1 of a lactometer degree ($7 \times .3 = 2.1$). $110 + 2.1 = 112.1$, the true Board of Health Lactometer reading.

Problem No. XXI.

This problem illustrates the method of correcting for temperature on the Board of Health lactometer when the temperature of the milk is below 60° F. It will be noted that since the temperature of the milk is below 60° F. the density of the milk is more than it should be, and therefore the correction factor (.3 of a lactometer degree for every degree in temperature below 60° F.) is added to the reading indicated by the lactometer.

What would be the true reading of a sample of milk which gave a Board of Health reading of 112 at a temperature of 54° F.?

Since the instrument is graduated to be used at a temperature of 60° F., the sample is 6° F., colder than it should be to give a correct reading ($60 - 54 = 6$). The correction factor is .3 of a lactometer degree for every degree in temperature below 60° F., and for 6° F. it would be 1.8 lactometer degrees ($.3 \times 6 = 1.8$). $112 - 1.8 = 110.2$, the true Board of Health lactometer reading.

The following problem illustrates the use of Troy's formula in determining the solids not fat in a sample of milk when the Babcock fat reading and the Quevenne lactometer reading are given.

Problem No. XXII.

What would be the percentage of solids not fat in a sample of milk whose Quevenne lactometer reading was 32.4 and whose fat reading was 4.2?

Substituting in the formula $\frac{L + F}{4}$, $32.4 + 4.2 = 36.6$. $36.6 \div 4 = 9.15\%$ of solids not fat in the sample of milk.

The total percentage of solids would be obtained by adding the solids not fat to the fat reading $9.15 + 4.2 = 13.55\%$ of total solids.

COMPUTING ACIDITY OF MILK

In the following problem is illustrated the method of computing the acidity of milk when an n/10 alkali solution is used to neutralize the acid in the milk.

Problem No. XXIII.

It required 4 c.c. of an n/10 alkali solution to neutralize the acid in 20 grams of milk. What was the percentage of acid in the milk?

One c.c. of n/10 alkali will neutralize .009 grams of lactic acid. 4 c.c. would neutralize 4 times .009 grams or .036 grams of lactic acid ($.009 \times 4 = .036$). The .036 is the number of grams of acid in the 20 grams of milk and if the weight of the acid (.036) is divided by the weight of the milk (20) and the quotient multiplied by 100, the percentage of acid will be obtained $.036 \div 20 = .0018 \times 100 = .18\%$ acid.

Problem No. XXIV.

In this problem is illustrated the method of determining the strength of an alkali tablet solution made by dissolving a definite number of alkali tablets in a given quantity of water. The strength of the alkali tablet solution is reckoned in terms of the number of grams of lactic acid which each c.c. of the solution will neutralize.

What would be the strength per c.c. of an alkali tablet solution made by dissolving five alkali tablets in 30 c.c. of water? One alkali tablet will neutralize .03492 grams of lactic acid. 5 tablets will neutralize $5 \times .03492 = .17460$ grams of lactic acid. The five tablets were dissolved in 30 c.c. of water, so each c.c. would have a strength represented by the number of times 30 is contained in .17460 which is .00582 ($.17460 \div 30 = .00582$).

Problem No. XXV.

In this problem is illustrated the method of computing the strength of an alkali tablet solution and also of using this same solution to determine the percentage of acid in a given amount of milk.

An alkali tablet solution was made by dissolving 8 alkali tablets in 45 c.c. of water. It required 5 c.c. of this solution to neutralize the acid in 20 grams of milk. What was the percentage of acid in the milk?

One alkali tablet would neutralize .03492 grams of lactic acid. 8 tablets would neutralize 8 × .03492 grams = .27936 grams. The 8 tablets were dissolved in 45 c.c., so that each c.c. of the solution would have a strength represented by the number of times 45 is contained in .279369 or .006208 (.279360 ÷ 45 = .006208).

Since 1 c.c. of the alkali tablet would neutralize .006208 grams of lactic acid and it required 5 c.c. of the solution to neutralize the acid in 20 grams of milk there would be .031040 grams of acid in the milk (.006208 × 5 = .031040). .031040 ÷ 20 = .001552 × 100 = .1552% of acid in the milk.

BACTERIA IN MILK

The purpose of the next problem is to compute the numbers of bacteria per c.c. in a Petri plate when the number of colonies and the rate of dilution are given.

Problem No. XXVI.

One cubic centimeter of milk was diluted at the rate of 1:1000. The plate in which this dilution was placed showed a growth of 45 colonies. How many bacteria were there per c.c. in the milk examined?

The plate contained 45 colonies which grew from 1 c.c. of the diluted milk. The 1 c.c. which produced the 45 colonies was diluted 1000 times. One cubic centimeter of the original milk must therefore have contained 1000 times as many bacteria or 45,000 bacteria per c.c. (45 × 1000 = 45,000).

Problem No. XXVII.

The object of this problem is to show the method of computing the bacteria in a Petri plate when only ten square centimeters of the area of the plate are counted.

A sample of milk was diluted 1: 1000. One c.c. of this dilution was placed in a Petri plate and 10 square centimeters of this plate gave a total count of 285 colonies. How many bacteria per c.c. were there in the original milk?

If 10 square centimeters contained 285 colonies, 1 square centimeter would contain 1/10 as many or 28.5 colonies (285 ÷ 10 = 28.5). The Petri plate contains 64 square centimeters, therefore the plate would contain 1824 colonies. The cubic centimeter of milk

in the plate was diluted 1000 times, therefore the original milk would contain 1000 times as many bacteria per c.c. or 1,824,000 ($1824 \times 1000 = 1{,}824{,}000$).

Problem No. XXVIII.

This problem shows the method of computing the factor of a microscope. This factor is to be used in converting counts of bacteria in milk obtained by the direct microscopic method into equivalent terms of bacteria per c.c. of milk.

The diameter of the field of a microscope showed exactly 16 divisions on a micrometer. Each division of the micrometer had a value of .01 mm. Compute the factor necessary to use in converting the number of bacteria obtained by a direct microscopic examination of milk into equivalent terms of bacteria per c.c.

$16 \times .01 = .16$ mm. the diameter of the field of the microscope. πr^2 = the area of a circle. $.16 \div 2 = .08$, the radius of the field of the microscope. $(.08)^2 = .0064$. $.0064 \times 3.1416 = .02010624$ sq. m.m., area of field of microscope.

There would be as many fields in one sq. mm. as .02010624 is contained in 1 sq. mm. = 49.735 fields.

There are 100 c. mm. in 1 c.c., therefore the 49.735 would have to be multiplied by 100 to find the number of microscope fields in 1 c.c. ($49.735 \times 100 = 4973.5$). Since only .01 c.c. of milk were taken for examination, the number of fields per c.c. would have to be multiplied by 100 to give results in terms of bacteria per c.c. ($4973.5 \times 100 = 497350$ the factor of the microscope.) In this case the factor is so near 500,000 that it would be used instead of 497,350. Doing so would have a small influence on the results and would make computations easier.

Problem No. XXIX.

This problem illustrates the method of computing bacteria per c.c. in milk from a direct microscope count.

In the examination of a sample of milk for bacteria by the direct microscopic method two sources were found in 40 fields. Using the microscopic factor given in Problem XXVIII (497350), how many bacteria per c.c. were there in the milk?

If there were 2 sources in 40 fields, there would be .05 sources in 1 field ($2 \div 40 = .05$). In 497350 fields there would be $.05 \times 497350 = 24867+$ bacteria per c.c.

REFRIGERATION WITH ICE AND SALT

This next illustrates the method of computing the refrigeration available with a given percentage of ice and salt. In working this problem it will be necessary to refer to Table 61, which gives the temperature obtained per pound of mixture with different percentages of ice and salt.

Problem No. XXX.

How much refrigeration would be available with 807.50 pounds of ice and 142.50 pounds of salt?

This would make a total mixture of 950 lbs. and by dividing the 142.50 by 950 and multiplying the product by 100, it will be found that this is a 15% brine mixture, $(142.50 - 950) \times 100 = 15\%$.

By referring to Table 61 it will be found that a 15% brine has available 133 B.T.U. per pound, therefore the 950 pounds mixture would have available $950 \times 133 = 126{,}350$ B.T.U.

Problem No. XXXI.

Ice and salt are sometimes added to a tank of water, the temperature of which is above 32° F., and the salt itself is seldom as low as 32° F. In such a case both the water and salt must be lowered to 32° F., and this, of course, detracts from the efficiency of the brine mixture for cooling purposes.

Suppose 807.50 pounds of ice are mixed with 142.50 pounds of salt. The salt is at a temperature of 55° F., and the salt and ice are placed in 200 pounds of water whose temperature is 60° F. What would be the total number of B.T.U. available for refrigeration?

The 950 pounds mixture $(142.50 + 807.50 = 950)$ would make a 15% brine which would have available 133 B.T.U. per pound or a total available refrigeration of 126,350 B.T.U. $(133 \times 950 = 126{,}350)$. Since the salt must be cooled from 55° F. to 32° F. or 23 degrees $(55 - 32 = 23)$ the B.T.U. necessary to cool the salt must be subtracted from the available refrigeration. The specific heat of salt is .214. Multiplying 142.50 by .214 we get 30.495, which is the amount of heat necessary to change the temperature of the 142.50 pounds of salt 1 degree as compared with the same amount of water. But the salt must be lowered 23 degrees and it would, therefore, require 701.385 B.T.U. $(30.495 \times 23 = 701.385)$. The

200 pounds of water must be cooled from 60° F. to 32° F. or a total of 28° F. This would require 28 × 200 or 5600 B.T.U.

The salt and the water would, therefore, detract from the available refrigeration 6301.385 B.T.U. (701.385 + 5600 = 6301.385). This would leave available for cooling purposes 120,048.615 B.T.U. (126,350 — 6301.385 = 120,048.615).

ICE REQUIRED TO COOL MILK

The next problem illustrates the method of calculating the pounds of ice required to cool a given amount of milk when the milk is to be cooled to 32° F.

Problem No. XXXII.

How many pounds of ice will be required to cool 300 pounds of milk from 90° F. to 32° F., assuming that the specific heat of the milk is .93? 300 × .93 = 279, which is the B.T.U. required to change the temperature of the 300 pounds of milk one degree as compared with the same amount of water. It is desired to change the temperature of the milk 58° (90 — 32 = 58). Therefore, 279 × 58 = 16,182 B.T.U. to be extracted from the 300 pounds of milk. Since 1 pound of ice will extract 144 B.T.U. it will take as many pounds of ice as 144 is contained in 16,182 or 112.3 pounds of ice (16,182 ÷ 144 = 112.3).

Problem No. XXXIII.

The following problem illustrates the method of computing the number of pounds of ice required to cool a given quantity of milk when the final temperature desired is above 32° F.

How many pounds of ice will be required to cool 300 pounds of milk from 90° F. to 40° F., assuming the specific heat of milk to be .93? 300 × .93 = 279, the number of B.T.U. required to change the temperature of the 300 pounds of milk one degree, as compared with the same amount of water. It is desired to change the temperature of the milk 50° (90 — 40 = 50). Therefore, 279 × 50 = 13,950, the number of B.T.U. to be extracted from the 300 pounds of milk. The temperature to which the milk is to be cooled is 8° above 32 (40 — 32 = 8). The efficiency of a pound of ice is increased because it does not take as many B.T.U. to change the temperature of the milk above 32° F. as it does at 32° F. It requires 180 B.T.U.

to change the temperature of a pound of water at 32° F. to water at 212° F., or 1 B.T.U. is required for each degree. Therefore, in this case to find the amount of ice required we should now find the difference between 40 and 32 (40 — 32 = 8) and add this difference to 144, making 152 (144 + 8 = 152). The number of heat units to be extracted should then be divided by 152, making 91.77 pounds of ice required to cool the 300 pounds of milk from 90 to 40 (13,950 ÷ 152 = 91.77).

CHANGING FAHRENHEIT READINGS TO CENTIGRADE READINGS AND CENTIGRADE READINGS TO FAHRENHEIT READINGS

The boiling point on the scale of the Fahrenheit thermometer is placed at 212° above zero and the freezing point on the same scale is placed at 32° above zero.

On the scale of the Centigrade thermometer the boiling point is placed at 100° and the freezing point at 0°.

Since the boiling point on the Fahrenheit thermometer is at 212° and the freezing point is at 32°, there is a difference of 180° between the freezing and the boiling point (212 — 32 = 180).

Since the boiling point on the Centigrade thermometer is 100° and the freezing point is at 0°, there is a difference of 100° between the freezing and boiling point.

Therefore in comparing the scales of the two thermometers;

100° C. = 180° F., or,
1° C. = 1.8° F.

To change from Fahrenheit to Centigrade scale, subtract 32 from the Fahrenheit reading and divide the remainder by 1.8.

Expressed in terms of a formula this rule would read as follows:

(Degrees F. — 32) ÷ 1.8 = Degrees C.

To change from the Centigrade to the Fahrenheit scale, multiply the Centigrade reading by 1.8, and to the result add 32.

Expressed in terms of a formula, this rule would be as follows:

(Degrees C. × 1.8) + 32 = Degrees F.

The following problems will illustrate the method of application of these two rules.

Problem No. XXXIV.

145° F. would be the equivalent of how many degrees C.?

$145 - 32 = 113.$ $\quad 113 \div 1.8 = 62.7°$ C.

Problem No. XXXV.

37° C. would be the equivalent of how many degrees F.?

$37 \times 1.8 = 66.6.$ $\quad 66.6 + 32 = 98.6°$ C.

COMPARISON OF SOME ENGLISH AND METRIC WEIGHTS AND MEASURES

The following are some English and Metric equivalents which are in most common use. It is frequently convenient to use these equivalents in laboratory work.

One inch = 2.54 centimeters
One foot = .3048 meters
One yard = .9194 meters

One cu. inch = 16.39 cc.
One cu. foot = .02832 cu. meters
One cu. yard = .7646 cu. meters

One square inch = 6.452 square centimeters
One square foot = .0929 square meters
One square yard = .8361 square meters

One quart = .9465 liter
One gallon = 3.786 liters
One fluid ounce = 29.578 c.c. (usually considered 30 c.c.)
One ounce avoirdupois = 28.3495 grams
One pound = .45392 kilo = 453.920 grams

One millimeter = .03937 inch
One decimeter = 3.937 inches
One meter = 39.37 inches
One meter = 3.281 feet
One meter = 1.0936 yards

One milligram = .0154 grains
One gram = .03572 ounce
One kilo = 2.2046 pounds

One liter = 1.0567 quarts
One liter = .2641 gallons

One cc. = 1 gram
One micron (μ) = 1/1000 mm. or 1/25000 inches

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